Not to be cited without the permission of the authors[1]

Canadian Atlantic Fisheries Scientific Advisory Committee

CAFSAC Research Document 88/52

Ne pas citer sans l'autorisation des auteurs[1]

Comité scientifique consultatif des pêches canadiennes dans l'Atlantique

CSCPCA Document de recherche 88/ 52

An Assessment of the West Coast of Newfoundland (NAFO Division 4R) Herring Resource in 1987

by

I. H. McQuinn

Ministère des Pêches et des Océans
Division de la Recherche sur les Pêches
Institut Maurice-Lamontagne
C.P. 1000
Mont-Joli (Québec)
G5H 3Z4

[1]This series documents the scientific basis for fisheries management advice in Atlantic Canada. As such, it addresses the issues of the day in the time frames required and the Research Documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research Documents are produced in the official language in which they are provided to the Secretariat by the authors.

[1]Cette série documente les bases scientifiques des conseils de gestion des pêches sur la côte atlantique du Canada. Comme telle, elle couvre les problèmes actuels selon les échéanciers voulus et les Documents de recherche qu'elle contient ne doivent pas être considerés comme des énoncés finals sur les sujets traités mais plutôt comme des rapports d'étape sur les études en cours.

Les Documents de recherche sont publiés dans la langue officielle utilisée par les auteurs dans le manuscrit envoyé au secrétariat.

ABSTRACT

Herring landings in NAFO Division 4R reached only 16,600 t in 1987, despite a TAC of 30,600 t, mainly due to market and plant-capacity limitations. Spring spawners have dominated the annual catch since 1973. Historically, this spawning group has been dominated by the 1968 and 1974 year-classes. However in 1987, the 1980 and 1982 year-classes comprised 74% of the catch in numbers. The fall spawners had been dominated by the 11+ age group until 1983. In 1987, the 1979 year-class made up 47% of the catch in numbers. Cohort analyses showed that the spring spawner 5+ biomass stands at 128,000 t in 1987, near 1975 levels. The fall spawner 6+ biomass has increased to 76,000 t in 1987 from a low of 12,000 t in 1983. The strong recruitment of the 1979, 1980 and 1982 year-classes has resulted in a significant increase in abundance of these two stocks. Projections using a fishing mortality of 0.3 would result in a catch of 31,200 t of spring spawners in 1988 and 22,800 t in 1989. The $F_{0.1}$ fall spawner catch would be 20,900 t in 1988 and 15,400 t in 1989.

RESUME

Les débarquements de hareng de la division 4R de l'OPANO n'ont atteint que 16 600 t en 1987, malgré un TPA de 30 600 t, surtout à cause des marchés et de la capacité des usines. Les reproducteurs de printemps dominent la capture annuelle depuis 1973. Les classes d'âge de 1968 et 1974 ont dominé historiquement les captures de ce groupe reproducteur. Cependant, les classes d'âge de 1980 et 1982 ont représenté 74 % de la capture en nombres en 1987. Les poissons agés de 11 ans et plus, dominaient les captures de reproducteurs d'automne jusqu'à 1983. En 1987, la classe d'âge de 1979 a dominé la capture en nombres (47 %). L'analyse de cohorte a démontré que la biomasse (5+) de reproducteurs de printemps a atteint 128 000 t en 1987 ce qui est près du niveau de 1975. La biomasse (6+) de reproducteurs d'automne a augmenté à 76 000 t en 1987, comparée à 12 000 t en 1983. La cause des hausses observées est attribuée au recrutement des classes d'âge de 1979, 1980 et 1982. Un taux de mortalité par la pêche de 0,3 exercé sur les reproducteurs de printemps résulterait en une capture de 31 200 t en 1988 et de 22 800 t en 1989. Les captures de reproducteurs d'automne à un taux de mortalité à $F_{0,1}$ seraient de 20 900 t en 1988 et de 15 400 t en 1989.

INTRODUCTION

Herring in NAFO division 4R (Figure 1) have been assessed by CAFSAC as a single management unit since 1977 (Moores and Winters, 1977). In summarizing the available information on the 4R herring stock structure, Moores (1983) stated that "the definition of the management unit to encompass this stock was based primarily on external tagging studies, conducted since 1975, which indicate that the west coast of Newfoundland was discrete from adjacent stock areas". Although there were indications from sampling and tagging data that herring concentrations exploited in St. George's Bay in the spring fishery between 1967 and 1972 were possibly a mixture of west coast and southern Gulf stocks, Moores (1983) concluded that herring caught in this area since 1973 were primarily of west coast origin.

As in previous years, the west coast of Newfoundland herring resource has been assessed separately for spring and fall spawners as determined from their gonadal development or, in the case of immature fish, from their otolith characteristics. It is generally accepted that these two spawning components have different life histories and therefore should be treated as two unit stocks.

Management Plan:

Total allowable catches (TAC) have been in effect since 1977, when the west coast of Newfoundland was defined as a herring management unit. In order to prevent over-exploitation of local stocks, the Atlantic Herring Management Committee originally allocated the TAC into quotas for three areas: (1) St. Georges Bay (area 4Rd), (2) Cape St. George to Cape St. Gregory (area 4Rc) and (3) Cape St. Gregory to Cape Norman (areas 4Rb and 4Ra) (Moores and Winters, 1978). In recent years, 45% of the TAC has been allocated to the fixed gear sector (mainly anchored gillnets) and 55% to the mobile gear sector (mainly purse seines). In addition, the purse seine quota has been proportioned among the five remaining vessels and the gillnet allocation has been divided evenly between the regions north and south of Cape St. Gregory. However, despite these management initiatives, the TAC has been exceeded every year except in 1981 and 1987 (Table 1; Figure 2).

Historical Fishing Patterns:

Total herring landings from the west coast of Newfoundland were relatively constant from 1966 to 1970, ranging between 3,000 and 6,000 t (Table 1, Figure 2). A marked increase in catches began in 1971 which peaked at 27,000 t in 1973, as plant processors shifted from fish meal production to barrelled products for human consumption subsequent to the decline of the North Sea herring stocks. Landings in 4R decreased sharply in 1974 and 1975 as the purse seine fleet shifted its activities to the overwintering herring concentrations in NAFO division 4Vn. A steady increase in landings again occurred between 1976 and 1980, a trend which was reversed in 1981, mainly due to depressed markets. Improved market conditions in 1985 allowed for a large increase in landings which reached a peak of 21,400 t in 1986, declining slightly to 16,500 t in 1987. As in previous years, the decline in catches in 1987 was mainly due to market and plant-capacity limitations.

The fishing pattern of the combined fixed and mobile herring fleet has varied greatly over time. Before 1971, most of the catch was reported in

area 4Rb (Bonne Bay), while from 1971 to 1978, area 4Rd (St. Georges Bay) was the single most important fishing zone (Figure 3a). More recently, the proportion of the total catch reported in area 4Rd has slowly diminished while increasing in area 4Rc (Bay of Islands and Port-au-Port Bay) and again in area 4Rb.

The purse seine fleet, being very mobile, can direct its fishing effort wherever success and markets are optimal. The fishing pattern of the fleet has therefore fluctuated considerably over time (Figure 3b) in response to shifting concentrations of herring schools and their accessibility to buyers. In the latter half of the 1960's, almost 100% of the purse seine catches came from 4Rb. During the 1970's, the fleet shifted its fishing activity northward to 4Ra (St. John Bay) and southward to 4Rd, where most of the catch was reported. In the early 1980's, the proportion of market size fish decreased in St. Georges Bay due to the presence of large schools of juvenile herring (the abundant 1980 and 1982 year-classes). Consequently, throughout the mid-1980's the purse seiners concentrated more and more of their efforts during the spring fishery in area 4Rc. However, as a proportion of the total catch, this fishery was declining in importance. Since 1982, purse seine catches have been taken almost exclusively from overwintering concentrations in areas 4Rb and 4Rc from October to December (Table 2). Since 1986, over 80% of the purse seine landings were reported during this fall fishery.

The nearshore fishery, made up of all gears other than purse seines (although mostly gillnets), has also gone through pronounced changes since 1966. In the late sixties, the dominance of this fishery in the southern areas rapidly declined (Figure 3c). From 1971 to 1978, most of the catch was reported from area 4Ra. After 1975, a major spring gillnet fishery developed south of Cape St. Gregory (Moores and Winters, 1980), resulting in a steady increase in landings reported from areas 4Rc and 4Rd until 1982. In recent years, almost equal proportions of the total gillnet catch have been taken from spawning concentrations in St. Georges Bay and Port-au-Port Bay in April and May, and north of Pointe Riche from July to September (Table 2; Figure 3c), although a relatively active late fall fishery has occurred sporadically in areas 4Ra to 4Rc throughout this period.

Total gillnet landings have declined since 1980 (Table 1), resulting in a decline in the proportion of the total catch taken by gillnets since 1980 (Figure 4). In 1985 and 1986, less than 10% of the total landings were reported from the gillnet fishery as there has been little market demand for gillnetted herring. The inshore proportion of the total catch did however increase to 17% in 1987.

SEQUENTIAL POPULATION ANALYSES

A) Input Data:

1. Age Composition of the Commercial Catch:

Random samples from the commercial fishery were collected by port samplers, by gillnet fishermen hired to keep detailed catch and effort data on herring caught on the spawning grounds, and by observers aboard the purse seine vessels. Because of the number of people involved, most of the major commercial landings were well sampled (Annex 1). These samples were frozen

and sent to the Quebec Region laboratory for analyses (length, weight, gonad weight, maturity stage, and otolith collection and analyses).

Individual herring were assigned as either spring or fall spawners by relating the maturity stage, estimated from a gonadosomatic index (GSI) by discriminant analyses (McQuinn, 1988), to the date of capture, using the 4R maturity cycle chart (McQuinn, 1987a). Ages were determined from the otoliths as the number of winter rings for spring spawners and the number of winter rings plus one for fall spawners (Cleary et al., 1982). All herring with more than 11 rings were aggregated into an 11+ age group. The 1987 catch at age was then generated for spring and fall spawners as described by McQuinn, 1987c (CATΔAGE v1.0, Anon, 1986).

The spring spawner catch at age:

Spring spawners have dominated the catch in every year since 1973 (Table 3), averaging 72.5% of the catch in numbers. The 1968 year-class was the largest ever observed in the spring spawner catch and completely dominated from 1973 to 1978 (Table 4). Between 1973 and 1982, the only significant recruitment to the spring spawning stock came from the 1974 year-class. In 1983 about 30% of the catch consisted of the 1979 and 1980 year-classes, which again dominated the 1984 fishery, representing 59% of the catch in numbers. In 1985, the 1980 year-class was the dominant cohort and the most important since the 1966, contributing to 63% of the catch in numbers, and again 51% in 1986. In 1987, the 1982 year-class contributed to 40% of the spring spawner catch in numbers, maintaining the mean age of the spring spawners at 5.9 years old.

The fall spawner catch at age:

Herring of the 11+ age group have historically dominated the fall spawner catch (Table 4). In 1984, the 1979 year-class strongly recruited into the fishery and contributed to more than 49% of the catch in numbers. In 1985, this same cohort increased its dominance to an historical high of 63%, declining to 50% in 1986 and 47% in 1987. The mean age of fall spawners in the catch has therefore risen in recent years, from 6.0 years old in 1985 to 7.1 years old in 1987. However, this stock also appears to have several above average year-classes (1980, 1981 and 1982) helping to maintain the fishery.

2. Population Abundance Indices:

Abundance indices were estimated from commercial catch and effort data from the gillnet fishery for both the spring and fall spawners and from the purse seine fall fishery for both stocks combined.

Gillnet catch rates:

Commercial catch and effort data were obtained from all available purchase slips from 1977 to 1987. Annual gillnet catch rates were estimated from these data and standardized using a multiplicative model (Gavaris, 1980). The categories for the model were month, unit area and year. Catches in each category were proportioned to spring and fall spawners using the percent spawning stock composition determined from the commercial samples (Table 5).

The total effort for each category (number of boat-days) was adjusted on the basis of gang size estimates for each area, standardized to 1 in 1978, to account for interannual changes in the number of nets fished per day (Table 6). Analyses of inter-monthly variability showed that it was not necessary to adjust effort for seasonal trends in gang size.

The estimated number of nets per gang for 1977 to 1981 were based on telephone surveys conducted on the Newfoundland east coast (Wheeler and Winters, 1983). For 1982 to 1986, the gang sizes were obtained from written surveys sent between 1984 to 1987 to all licensed fishermen along the west coast. The number of nets fished from 1981 to 1983, recorded on the licence applications, was used to standardize the two series of data. The gang size estimates for 1982 to 1987 were calculated using the average number of nets fished by those fishermen within each area who sold the majority of their catches, so as not to include bait fishermen who did not receive purchase slips.

The catch rate indices were thus calculated as:

$$U_{mut} = \frac{C_{mut}}{E_{mut} \times GS_{ut}} \qquad (1)$$

where U_{mut} is the catch rate in month m, unit area u and year t,
C_{mut} is the catch biomass in month m, unit area u and year t,
E_{mut} is the effort (number of boat-days) in month m, unit area u and year t,
GS_{ut} is the standardized gang size in unit area u and year t.

A multiplicative model (STANDAR v1.0, Anon, 1986) was then fitted to these catch and effort data (Tables 7 and 8) to yield standardized annual catch rates for each spawning stock. Initial analyses showed that an unweighted regression resulted in significant trends in the residuals of the model. Because of the inherent high variability of these data (e.g. varying number of nets used by each fisherman), a regression weighted on catch and effort was used to lessen the effect of those cells with very few slips (i.e. <10) using the following equation:

$$\text{Weight} = (\text{Catch} \times \text{Effort})^{.25} \qquad (2)$$

An examination of the residuals of this weighted model indicated a good model fit (Figures 5 and 6). All the categories were significant ($P<0.05$), with an r^2 of 0.64 and 0.66 for the spring and fall spawners, respectively. These catch rates (Table 9, Figures 7 and 8) were used to calibrate the cohort analyses for the two spawning stocks.

The spring spawner gillnet catch rates followed a sharp decrease from 1978 to 1981 after an initial increase from 1977, decreased slightly until 1985 and then increased sharply to 1987 (Figure 7). The fall spawner catch rates declined from 1977 to 1982, remained relatively stable to 1983, and has increased sharply to 1987 (Figure 8).

Purse seine catch rates:

Catch and effort data from purse seine observer logbooks have also been analyzed for trends in abundance. Data were available for the fall fishery (October to December in 4Rb) in 1982 and from 1984 to 1987. Catch rates, weighted by the corresponding purse seine catches, were calculated for these selected months and areas. Trends in catch/set and catch/night were very similar (Figure 9), both of which increased slowly between 1982 to 1984, increased more sharply from 1984 to 1986, and remained stable or declined slightly in 1987. The majority of the catch (60 to 80%) in this fishery over the time period has been spring spawners (Table 10).

It should be noted that the validity of purse seine catch rates as pelagic fish population abundance indices has often been questionned and it is generally acknowledged that they are difficult to interpret (Pope, 1978; Ulltang, 1978; Powles, 1981; Cleary, 1982). Consequently, these data are presented only as additional information on trends in abundance.

B) Estimation of Parameters:

1. Natural Mortality Rate:

A value of 0.2 was assumed for the instantaneous natural mortality rate (M) in the present analyses. This value was used in the previous assessment (McQuinn, 1987b) and is consistent with estimates made for other herring stocks (Lea, 1930; Runnström, 1936; Beverton, 1963).

2. Partial Recruitment:

A number of relationships were examined to estimate partial recruitment for ages 4+, including historical trends. However it was felt that the historical trends were inappropriate as the fishery and the age composition of the catch had changed considerably since this period and would not reflect present conditions. Last year's vectors were therefore used as these values were derived from selectivity coefficients from the 1985 purse seine fishery and were the best available estimates. These values were estimated for ages 4, 5 and 6 from the ratio of the proportion at age from the commercial landings and the purse seine discarded sets (McQuinn, 1986). Spring spawners 5 years and older and fall spawners 6 years and older were assumed to be fully recruited. The partial recruitment values for ages 2 and 3 were set to yield the historical geometric mean population numbers from 1973 to 1985 to simulate average recruitment. The partial recruitment values obtained were as follows:

Age	2	3	4	5	6	7+
Spring	.093	.08	.63	1.00	1.00	1.00
Fall	.001	.11	.26	.63	1.00	1.00

A comparison of the 1987 percent age composition projected by McQuinn (1987b) with the observed 1987 catch at age:

Age	2	3	4	5	6	7	8	9	10	11+
					Spring Spawners					
Projected	.7[1]	5.2[1]	7.2[1]	31.7	4.6	39.8	7.2	.6	.2	2.6
Observed	1.2	.9	2.2	39.8	9.1	33.8	4.5	.5	.1	2.1
					Fall Spawners					
Projected	.2[1]	2.9[1]	2.8[1]	17.5	20.0	10.7	39.1	3.7	1.8	1.4
Observed	.0	1.3	3.9	10.8	16.1	13.8	47.4	3.8	1.3	1.6

[1] From geometric mean recruitment

showed that these partial recruitment vectors from last year's assessment reasonably estimated the relative strengths of the various year-classes observed in 1987.

3. Fishing Mortality for the Oldest Ages:

The vector of fishing mortalities for the oldest ages (F_o) was estimated as described by McQuinn (1986) (FISHΔHER v1.0, Anon, 1986). This method assumes that the F for age 10 is equal to the F for ages 11+ and requires only a F value for age group 11+ in the last year as input. The resulting vector was used to start the cohort analysis at age 10. The 11+ population numbers are then concatenated to the population matrix.

4. Mean Weight at Age:

The annual weight at age for each spawning stock was estimated as the mean of the weight at age of each sample stratum and gear, weighted by their corresponding landings (McQuinn, 1987c)(WEIGHTΔAGE v1.0). These weight-at-age matrices (Table 11) were used to estimate the catch and population biomasses. Annual gillnet weight-at-age matrices were also calculated from the weighted mean gillnet weight at age (Table 12) which were used to estimate the average gillnet fishable biomass for each spawning stock for the calibration of the cohort analyses.

C) Calibration of Cohort Analyses:

A series of cohort analyses was run separately for spring and fall spawners at various values of terminal fishing mortality (F_t). Least squares regression of average gillnet fishable biomass, aggregated over ages, with standardized gillnet catch rate was used to calibrate the cohort analyses for the two stocks. The average gillnet fishable biomass (B_f) for each spawning stock was estimated from the beginning-of-the-year population numbers, the gillnet selectivity matrix (Table 13), and the average gillnet weight at age (White, 1986):

$$B_f = SNW(1-e^{-Z})/z \qquad (3)$$

where S is the gillnet selectivity matrix,
N is the beginning-of-the-year population numbers at age,
W is the average gillnet weight at age, and

z is the total mortality matrix.

The criteria examined for the selection of F_t, in order of priority, were (a) the correlation coefficient, (b) the sums of squares of the standardized residuals for the 1985 to 1987 points and (c) the closeness of the 1987 point to the regression line.

ASSESSMENT RESULTS AND DISCUSSION

The results of the calibrations of average gillnet fishable biomass (Table 14) on gillnet catch rate indicated terminal fishing mortalities in 1987 of 0.10 and 0.05 for spring and fall spawners, respectively (Table 15). The regression coefficients were 0.90 for both models, while the intercept was significantly different from zero for the fall spawners but not so for the spring spawners (Figure 10). The choice of F_t for the fall spawners was not obvious from the calibration criteria (Table 15), although an F_t of 0.05 yielded a population biomass estimate only slightly higher than that estimated from last year's assessment. It can also be seen from Figure 10 that the 1987 point was highly influential on the fall spawner regression results. In addition, the cohort analyses did not converge for the major year-classes of both stocks due to the low fishing mortalities measured for these fisheries. Due to these uncertainties, the results of the analyses should be interpreted with caution.

The spring spawner 5+ population biomass at the beginning of the second quarter (Table 16, Figure 11), dropped steadily between 1973 and 1984, from 136,000 t to 31,000 t, even though the fully recruited fishing mortality (5+) was below the $F_{0.1}$ target of 0.3 in all years except 1982 and 1983 during this period (Table 17). The decline in this stock was primarily due to poor recruitment during the decade following the appearance of the strong 1968 year-class (Table 18). In 1985, the 5+ biomass more than tripled with the full recruitment of the 1980 year-class, and in 1987 has reached its highest level since 1975.

Similarly, the fall spawner 6+ mid-year biomass declined continuously between 1973 and 1984, from 77,000 t to 15,000 t (Table 19, Figure 11), again even though the fully recruited fishing mortality (6+) had been below $F_{0.1}$ since 1973 (Table 20). Poor recruitment subsequent to the entry of the strong 1958 and 1963 year-classes was the major factor contributing to the decline of this stock (Table 21). The 6+ fall spawner biomass increased almost five-fold in 1985, exceeding 1974 levels, as the 1979 year-class became fully recruited, and is now near the highest value of the series.

PROGNOSIS

Projections for 1988 and 1989 were run assuming catches at $F_{0.1}$ (F_t=0.30). The input parameters used in the projections were (a) population numbers in 1987 obtained from the cohort analyses, (b) the 1987 partial recruitment vectors with recruitment at age 2 for 1988 and 1989 set to the geometric mean from 1973 to 1985, and (c) the observed 1987 catch at age and weight at age.

The results of these projections indicated an $F_{0.1}$ spring spawner catch of 31,000 t in 1988, and 23,000 t in 1989 (Table 22) and a decrease in population biomass from 143,000 t in 1988 to 109,000 t in 1989. A fall

spawner catch of 21,000 t in 1988, and 15,000 t in 1989 (Table 23) would result in a drop in the population biomass from 94,000 t in 1988 to 72,000 t in 1989. These analyses suggest that both the spring and fall spawning components are presently being exploited below the target fishing mortality of 0.3. However, assuming average recruitment between 1986 and 1989, it is expected that the population numbers will continue to decline, albeit gradually.

This year's assessment and projections resulted in an even more optimistic view of the resource than last year, particularly for the spring spawners. A sharp increase in the catch rates between 1984 and 1987 due to the recruitment of the strong 1980 and 1982 spring spawner and 1979 autumn spawner year-classes, which are now fully recruited to the gillnet fishery, strongly indicated that these stocks have recovered from the low population biomasses of the early 1980's.

ACKNOWLEDGEMENTS

I would like to gratefully acknowledge the contributions made by Joanne Hamel for her diligent and expert assistance with the collection, compilation, editing and processing of the data, and production of the graphics.

REFERENCES

Anon. 1986. CAFSAC Assessment Software Catalog. Assessment Computation Working Group of the CAFSAC Statistics, Sampling and Surveys Subcommittee. CAFSAC Res. Doc. 86/96, 24p.

Beverton, R.J.H. 1963. Maturation, growth and mortality of clupeid and engraulid stocks in relation to fishing. Rapp. P.-v. Réun. Cons. int. Explor. Mer. 154: 44-67.

Cleary, L. 1982. Assessment of the 4T herring stock. CAFSAC Res. Doc. 82/47, 43p.

Cleary, L., J.J. Hunt, J. Moores and D. Tremblay. 1982. Herring aging workshop, St. John's, Newfoundland, March - 1982. CAFSAC Res. Doc. 82/41, 10p.

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can J. Fish. Aquat. Sci. 37: 2272-2275.

Lea, E. 1930. Report on age and growth of the herring in Canadian waters. Rapp. Cons. Explor. Mer. 65: 100.

McQuinn, I.H. 1986. Assessment of the west coast of Newfoundland herring stocks in 1985. CAFSAC Res. Doc. 86/68, 41p.

McQuinn. I.H. 1987a. New maturity cycle charts for the herring stocks along the west coast of Newfoundland (NAFO division 4R) and the north shore of Quebec (NAFO Division 4S). CAFSAC Res. Doc. 87/66, 11p.

McQuinn, I.H. 1987b. A re-evaluation of the west coast of Newfoundland herring resourse (NAFO Div. 4R). CAFSAC Res. Doc. 87/67, 37p.

McQuinn. I.H. 1987c. Revisions to the 4R herring catch-at-age matrices. CAFSAC Res. Doc. 87/68, 23p.

McQuinn, I.H. 1988. The identification of spring and autumn spawning herring (Clupea harengus harengus L.) using maturity stages estimated from a gonadosomatic index. Can. J. Fish. Aquat. Sci. (in press).

Moores, J.A. 1983. A re-examination of the catch matrix utilized for the assessment of the Newfoundland west coast herring stock. CAFSAC Res. Doc. 83/6, 25p.

Moores, J.A. and G.H. Winters. 1977. Production and yield of western Newfoundland herring stocks. CAFSAC Res. Doc. 77/3, 17p.

Moores, J.A. and G.H. Winters. 19 8. The Newfoundland west coast herring stocks. CAFSAC Res. Doc. 78/2, 20p.

Moores, J.A. and G.H. Winters. 1980. An assessment of the status of the Newfoundland west coast herring stock. CAFSAC Res. Doc. 80/51, 25p.

Pope, J.G. 1978. Some consequences for fisheries management of the aspects of the behaviour of pelagic fish. ICES Symp. Biol. Basis Pel. Fish Stock Management, No. 12: 1-27.

Powles, H. 1981. What does purse seine catch per unit effort measure? A simple fishery model. CAFSAC Res. Doc. 81/36, 27p.

Runnström, S. 1936. A study of the life history and migrations of the Norwegian spring herring based on an analysis of the winter rings and summer zones on the scale. Fiskeridir. Skr. Havunders. 5(2): 1-103.

Ulltang, O. 1978. Catch per unit of effort in the purse seine fishery for Atlanto-Scandian (Norwegian spring spawning) herring. FAO Fish. Tech. Pap. 155: 91-101.

Wheeler, J.P. and G.H. Winters. 1983. 1982 east coast Newfoundland herring assessment. CAFSAC Res. Doc. 83/18, 31p.

White, G.N. 1986. Calculation of mid-year estimates in SPA. CAFSAC Res. Doc. 86/75, 15p.

Table 1. Herring catches (t) by gear type and fishing area and total allowable catches from NAFO division 4R from 1966 to 1987.

YEAR	4Rd				4Rc				4Rb				4Ra				COMBINED				TAC
	Purse seine	Gill-net	Other gears*	Total	Purse seine	Gill-net	Other gears	Total	Purse seine	Gill-net	Other gears	Total	Purse seine	Gill-net	Other gears	Total	Purse seine	Gill-net	Other gears	Total	
1966	0	216	0	216	0	103	0	103	5491	39	0	5530	0	18	0	18	5491	376	0	5867	
1967	0	215	0	215	0	66	0	66	5464	76	0	5540	0	13	0	13	5464	370	0	5834	
1968	0	156	789	945	0	59	0	59	3776	67	136	3979	0	11	0	11	3776	293	925	4994	
1969	241	33	6	280	0	46	0	46	2344	201	4	2549	0	68	1	69	2585	348	11	2944	
1970	28	410	3	441	12	81	17	110	2939	526	4	3469	0	763	92	855	2979	1780	116	4875	
1971	3287	424	427	4138	2239	333	24	2596	725	405	21	1151	356	2252	11	2619	6607	3414	483	10504	
1972	4743	351	866	5960	727	134	64	925	1330	214	0	1544	0	4619	146	4765	6800	5318	1076	13194	
1973	12112	428	0	12540	2740	122	0	2862	1763	302	2	2067	3453	6047	15	9515	20068	6899	17	26984	
1974	2465	159	0	2624	756	96	4	856	439	456	47	942	1071	1959	5	3035	4731	2670	56	7457	
1975	3221	117	3	3341	0	97	16	113	0	216	26	242	0	1076	22	1098	3221	1506	67	4794	
1976	6067	496	3	6566	1956	111	2	2069	0	207	20	227	184	1477	140	1801	8207	2291	165	10663	
1977	5289	273	7	5569	2009	193	3	2205	0	125	31	156	2155	2428	183	4766	9453	3019	224	12696	12000
1978	6252	523	33	6808	1037	931	16	1984	0	284	81	365	1834	4103	22	5959	9123	5841	152	15116	12500
1979	4387	1641	3	6031	2774	2267	2	5043	2829	1048	121	3998	0	3247	7	3254	9990	8203	133	18326	12500
1980	3499	1557	41	5097	3703	3224	17	6944	2002	878	88	2968	428	3681	5	4114	9632	9340	151	19123	18000
1981	2269	1367	2	3638	3277	1623	0	4900	2037	912	140	3089	342	1600	27	1969	7925	5502	169	13596	16000
1982	0	1462	3	1465	5575	1572	11	7158	3973	517	58	4548	0	1675	1	1676	9548	5226	73	14847	10000
1983	0	1410	2	1412	3269	873	46	4188	3223	226	108	3557	787	1438	34	2259	7279	3947	190	11416	10000
1984	0	1006	1	1007	3023	902	0	3925	4166	554	2	4722	15	809	4	828	7206	3271	7	10482	10000
1985	1720	398	0	2118	1733	164	0	1897	9718	348	4	10070	0	295	6	301	13171	1205	10	14386	10000
1986	1854	273	0	2127	1586	1069	0	2655	15830	468	0	16298	0	337	0	337	19270	2147	0	21417	17000
1987	222	550	0	772	3183	1137	0	4320	10164	327	5	10496	164	829	0	993	13733	2843	5	16581	30600

* Includes shrimp trawl, bar seine, trap midwater trawl and otter trawl.

Table 2. Herring landings (t) in NAFO division 4R by gear type, unit area and month from 1982 to 1987.

GEAR	YEAR	AREA	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
PS	1982	4Ra													0
		4Rb										3062	911		3973
		4Rc				1785	1839				1951				5575
		4Rd													0
	1983	4Ra											604	183	787
		4Rb										480	2263	480	3223
		4Rc				2289	980								3269
		4Rd													0
	1984	4Ra											15		15
		4Rb				24						1090	1763	1289	4166
		4Rc	309			2714									3023
		4Rd													0
	1985	4Ra													0
		4Rb								482		526	5577	3133	9718
		4Rc					1464	99				170			1733
		4Rd					1720								1720
	1986	4Ra													0
		4Rb										3091	10608	2131	15830
		4Rc					1400		186						1586
		4Rd				185	1669								1854
	1987	4Ra											164		164
		4Rb					25			14		748	4426	4951	10164
		4Rc					1319	596			153	565	379	171	3183
		4Rd					222								222
GN	1982	4Ra					2	28	532	350	51	621	83	8	1675
		4Rb					44	29	55	12	49	249	80		518
		4Rc				38	1135	133	3	5	29	227	2		1572
		4Rd				12	1319	44	33	15	20	16	3		1462
	1983	4Ra				9	5	43	235	535	233	82	159	137	1438
		4Rb				29	48	9	23	18	6	25	29	39	226
		4Rc	2	1	5	394	358	44	36	26		2	2	3	873
		4Rd	1	2	15	887	429	29	25	12	3	5		2	1410
	1984	4Ra	19				1	47	99	154	131	225	122	11	809
		4Rb				64	117	82	3	2	59	76	138	13	554
		4Rc				248	208	47	24	15	7	199	106	48	902
		4Rd				253	673	30	21	9	8	8	3	1	1006
	1985	4Ra					1	4		20	152	2	112	4	295
		4Rb				1	22	38	2	11	6	26	234	8	348
		4Rc				2	93	28	11	9	4	11	1	5	164
		4Rd					324	28	19	5	11	10		1	398
	1986	4Ra					65	84	19	48	28	68	14	11	337
		4Rb				6	48	46	14	9	8	136	171	30	468
		4Rc				132	319	105	21	10	8	141	319	14	1069
		4Rd				100	83	49	21	10	10				273
	1987	4Ra					19	21	14	142	65	192	353	23	829
		4Rb	1		1	15	22	23	11	7	5	87	135	20	327
		4Rc				146	580	96	77	52	13	55	117	1	1137
		4Rd				146	319	30	22	8	8	13	4		550

Table 3. Spring and fall spawner catch at age ($x10^{-3}$) and proportion of spring spawners in NAFO division 4R herring landings from 1973 to 1987.

SPRING SPAWNERS

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	0	0	0	0	45	0	0	3	13	0	4	39	48	265	323
2	1833	141	57	484	10	0	167	300	40	594	34	198	362	323	455
3	435	261	996	680	534	47	25	854	417	2374	2965	433	4587	2348	329
4	1063	130	420	846	541	1987	214	106	2114	693	3562	7773	787	13762	2781
5	27872	371	100	201	409	207	10828	355	129	2452	1131	3809	21642	3349	15257
6	2570	9445	1063	350	304	679	617	13872	354	421	1091	595	3993	28781	3507
7	3222	318	8431	2802	348	241	1075	407	8872	2153	293	814	445	5241	12952
8	3232	851	317	15567	4362	2162	547	1344	188	6488	713	209	381	465	1736
9	2598	774	336	759	15959	8208	2772	247	515	704	2990	672	255	167	182
10	4789	490	244	3136	1694	15260	7404	1427	283	950	798	755	380	260	37
11+	5696	2175	665	3588	6003	5062	14032	20574	13181	12863	7975	4226	1764	1661	806
1+	53310	14955	12629	28413	30210	33851	37681	39488	26106	29692	21556	19523	34645	56621	38365

FALL SPAWNERS

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
2	0	0	0	0	0	0	0	15	0	101	15	0	15	35	0
3	1798	20	19	48	3	10	7	181	33	567	83	55	235	426	156
4	1180	393	40	272	169	27	116	136	524	1824	2330	668	1340	1431	487
5	1114	530	865	290	134	545	345	86	245	956	1356	6259	1907	2671	1354
6	2626	325	925	422	404	393	2689	176	90	509	1309	1147	9678	2292	2009
7	1527	592	107	561	721	1108	520	1729	295	140	506	908	902	8421	1728
8	2631	258	157	325	405	1689	1287	250	1234	377	159	220	622	794	5927
9	3830	308	147	253	342	503	1847	675	153	972	467	146	115	384	474
10	8265	313	218	88	293	341	468	308	124	315	618	268	36	66	163
11+	17653	5610	3371	4818	6646	6051	6286	5243	3369	2609	2824	3091	468	227	196
1+	40626	8348	5848	7076	9116	10668	13564	8799	6067	8371	9667	12762	15333	16745	12494

TOTAL (SPRING AND FALL)

1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
93937	23303	18477	35489	39326	44520	51245	48288	32173	38062	31223	32286	49978	73366	50859

PERCENT SPRING SPAWNERS

1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
56.8	64.2	68.4	80.1	76.8	76.0	73.5	81.8	81.1	78.0	69.0	60.5	69.3	77.2	75.4

Table 4. Age composition (%) and mean age* of (A) spring and (B) fall spawners in NAFO division 4R herring landings from 1973 to 1987. Dominant year-classes have been underlined.

A) SPRING SPAWNER AGE COMPOSITION (pct)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	.0	.0	.0	.0	.1	.0	.0	.0	.1	.0	.0	.2	.1	.5	.8
2	3.4	.9	.5	1.7	.0	.0	.4	.8	.2	2.0	.2	1.0	1.0	.6	1.2
3	.8	1.7	7.9	2.4	1.8	.1	.1	2.2	1.6	8.0	13.8	2.2	13.2	4.1	.9
4	2.0	.9	3.3	3.0	1.8	5.9	.6	.3	8.1	2.3	16.5	39.8	2.3	24.3	7.2
5	52.3	2.5	.8	.7	1.4	.6	28.7	.9	.5	8.3	5.2	19.5	62.5	5.9	39.8
6	4.8	63.2	8.4	1.2	1.0	2.0	1.6	35.1	1.4	1.4	5.1	3.0	11.5	50.8	9.1
7	6.0	2.1	66.8	9.9	1.2	.7	2.9	1.0	34.0	7.3	1.4	4.2	1.3	9.3	33.8
8	6.1	5.7	2.5	54.8	14.4	6.4	1.5	3.4	.7	21.9	3.3	1.1	1.1	.8	4.5
9	4.9	5.2	2.7	2.7	52.8	24.2	7.4	.6	2.0	2.4	13.9	3.4	.7	.3	.5
10	9.0	3.3	1.9	11.0	5.6	45.1	19.6	3.6	1.1	3.2	3.7	3.9	1.1	.5	.1
11+	10.7	14.5	5.3	12.6	19.9	15.0	37.2	52.1	50.5	43.3	37.0	21.6	5.1	2.9	2.1

MEAN AGE* OF INDIVIDUALS IN CATCH

YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
MEAN AGE	6.50	7.02	6.81	8.14	9.00	9.29	8.61	8.74	8.76	8.43	7.69	6.31	5.25	5.59	5.90

B) FALL SPAWNER AGE COMPOSITION (pct)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.0	.0
2	.0	.0	.0	.0	.0	.0	.0	.2	.0	1.2	.2	.0	.1	.2	.0
3	4.4	.2	.3	.7	.0	.1	.1	2.1	.5	6.8	.9	.4	1.5	2.5	1.3
4	2.9	4.7	.7	3.8	1.9	.2	.9	1.5	8.6	21.8	24.1	5.2	8.7	8.5	3.9
5	2.7	6.4	14.8	4.1	1.5	5.1	2.5	1.0	4.0	11.4	14.0	49.0	12.4	15.9	10.8
6	6.5	3.9	15.8	6.0	4.4	3.7	19.8	2.0	1.5	6.1	13.5	9.0	63.1	13.7	16.1
7	3.8	7.1	1.8	7.9	7.9	10.4	3.8	19.7	4.9	1.7	5.2	7.1	5.9	50.3	13.8
8	6.5	3.1	2.7	4.6	4.4	15.8	9.5	2.8	20.3	4.5	1.6	1.7	4.1	4.7	47.4
9	9.4	3.7	2.5	3.6	3.8	4.7	13.6	7.7	2.5	11.6	4.8	1.1	.7	2.3	3.8
10	20.3	3.8	3.7	1.3	3.2	3.2	3.5	3.5	2.0	3.8	6.4	2.1	.2	.4	1.3
11+	43.5	67.2	57.6	68.1	72.9	56.7	46.3	59.6	55.5	31.2	29.2	24.2	3.1	1.4	1.6

MEAN AGE* OF INDIVIDUALS IN CATCH

YEAR	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
MEAN AGE	9.22	9.59	9.01	9.59	10.00	9.47	9.[illegible]	[illegible].49	9.16	7.36	7.29	6.83	5.98	6.33	7.10

* assuming ages 11+ to be 11.

Table 5. Proportion (%) of spring and fall spawning herring in the gillnet catch by month and fishing area, NAFO division 4R from 1973 to 1987.

	FISHING AREA																					
	4Rd			4Rc					4Rb							4Ra						
SPRING	APR	MAY	OCT	APR	MAY	JUN	SEPT	OCT	MAY	JUNE	JULY	SEPT	OCT	NOV	DEC	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1973											32.3		29.0	81.2				14.4				62.4	
1974										99.0					86.5				14.3			50.0	
1975		90.0								55.3	12.0												
1976		100.0								98.0								5.3				76.7	
1977										83.3	18.0				86.0		66.0	32.2	8.0	25.7	56.6	78.0	
1978		99.0							85.7	98.0							52.0	33.6				78.9	
1979	84.0		92.8						95.0					84.0				38.7	11.7	44.0	56.0		
1980	96.4			91.1					100.0					81.8		63.3	55.6	34.1	3.0	42.9	72.0	66.0	
1981				95.8					82.4	91.0							37.0	24.9	0.7			43.8	
1982					97.2									64.9				2.7					
1983		95.7										80.0	46.1	41.8				39.6	1.4	46.3	56.9	56.3	68.2
1984		94.1			78.5			84.0					60.2		44.9				8.6	27.9	63.0	36.0	52.7
1985		97.7			86.5	90.0												80.0	9.5	15.7		28.0	
1986	84.4	98.4		50.0	83.7		66.0	80.0						54.4				16.8	10.1	32.0	44.1	27.1	
1987	92.0	99.4		52.0	84.7	88.6							52.2						14.2	26.0	49.5	37.5	
FALL																							
1973											67.7		71.0	18.8				85.6				37.6	
1974										1.0					13.5				85.7			50.0	
1975		10.0								44.7	88.0												
1976		0.0								2.0								94.7				23.3	
1977										16.7	82.0				14.0		34.0	67.2	92.0	74.3	43.4	22.0	
1978		1.0							14.3	2.0							48.0	66.4				21.1	
1979	16.0			7.2					5.0					16.0				61.3	88.2	56.0	44.0		
1980	3.6			8.9					0.0					18.2		36.7	44.4	65.9	97.0	57.1	28.0	34.0	
1981				4.2					17.6	9.0							63.0	75.1	99.3			56.3	
1982					2.8									35.1				97.3					
1983		4.3										20.0	53.9	58.2				60.4	98.6	53.7	43.1	43.7	31.8
1984		5.9			21.5			16.0					39.8		55.1				91.4	72.1	37.0	64.0	47.3
1985		2.3			13.5	10.0												20.0	90.5	84.3		72.0	
1986	15.6	1.6		50.0	16.3		34.0	20.0						45.6				83.2	89.9	68.0	55.9	72.9	
1987	8.0	0.6		48.0	15.3	11.4							47.8						85.8	74.0	50.5	62.5	

Table 6. Gang size estimates by unit area, standardized to 1978, used to adjust the gillnet catch rates from 1977 to 1987 for the multiplicative model.

	4Ra		4Rb		4Rc		4Rd	
YEAR	GANG	n	GANG	n	GANG	n	GANG	n
1977	1.02	30	1.02	30	1.02	30	1.02	30
1978	1.00	90	1.00	90	1.00	90	1.00	90
1979	1.19	139	1.19	139	1.19	139	1.19	139
1980	1.31	149	1.31	149	1.31	149	1.31	149
1981	1.72	99	1.72	99	1.72	99	1.72	99
1982	1.84	129	2.04	132	2.16	97	1.66	87
1983	1.96	126	2.29	129	2.26	90	1.77	87
1984	1.99	115	2.41	124	2.44	72	2.05	93
1985	1.60	15		2.27	36[1]		2.06	22
1986	1.66	20		2.53	42[1]		1.22	8
1987	1.70	23		1.72	11[1]		0.95	9

[1] Estimates for 4Rb and 4Rc from 1985 to 1987 are combined.

Table 7. Analysis of variance and regression coefficients for the 1977 to 1987 gillnet spring spawner catch rate data.

REGRESSION OF MULTIPLICATIVE MODEL

Multiple R..... 0.803
Multiple R squared..... 0.644

ANALYSIS OF VARIANCE

Source of variation	DF	Sums of squares	Mean squares	F
Intercept	1	2.735E0001	2.735E0001	
Regression	22	1.211E0001	5.506E-001	19.185
(Month) Type 1	9	9.238E0000	1.026E0000	35.764
(Area) Type 2	3	2.302E-001	7.672E-002	2.673
(Year) Type 3	10	2.216E0000	2.216E-001	7.720
Residuals	233	6.687E0000	2.870E-002	
TOTAL	256	4.615E0001		

REGRESSION COEFFICIENTS

Category		Code	Variable	Coefficient	Std. Error	No. Obs.
1		5	Intercept	-0.133	0.239	256
2		4Rd				
3		77				
Month	1	3	1	-0.715	0.476	4
		4	2	-0.220	0.134	27
		6	3	-1.191	0.197	32
		7	4	-1.914	0.205	24
		8	5	-3.356	0.221	24
		9	6	-1.824	0.206	25
		10	7	-0.817	0.159	33
		11	8	-0.422	0.165	30
		12	9	-0.114	0.270	17
Area	2	4Ra	10	-0.117	0.170	73
		4Rb	11	-0.312	0.157	74
		4Rc	12	0.063	0.128	68
Year	3	78	13	0.392	0.250	25
		79	14	0.016	0.238	33
		80	15	0.086	0.238	25
		81	16	-0.495	0.246	27
		82	17	-0.540	0.251	20
		83	18	-0.622	0.247	23
		84	19	-0.600	0.245	26
		85	20	-0.666	0.317	20
		86	21	-0.001	0.283	25
		87	22	0.312	0.285	20

Table 8. Analysis of variance and regression coefficients for the 1977 to 1987 gillnet fall spawner catch rate data.

REGRESSION OF MULTIPLICATIVE MODEL

Multiple R..... 0.811
Multiple R squared..... 0.658

ANALYSIS OF VARIANCE

Source of variation	DF	Sums of squares	Mean squares	F
Intercept	1	5.629E0001	5.629E0001	
Regression	22	1.723E0001	7.830E-001	20.280
(Month) Type 1	9	4.404E0000	4.893E-001	12.673
(Area) Type 2	3	1.020E0000	3.399E-001	8.805
(Year) Type 3	10	1.572E0000	1.572E-001	4.073
Residuals	232	8.957E0000	3.861E-002	
TOTAL	255	8.247E0001		

REGRESSION COEFFICIENTS

Category		Code	Variable	Coefficient	Std. Error	No. Obs.
	1	8	Intercept	-0.530	0.247	255
	2	4Ra				
	3	77				
Month	1	3	1	-2.458	0.723	4
		4	2	-1.841	0.230	25
		5	3	-1.787	0.209	37
		6	4	-1.586	0.233	31
		7	5	-0.417	0.174	26
		9	6	-0.554	0.180	27
		10	7	-0.744	0.172	33
		11	8	-0.481	0.177	30
		12	9	-0.382	0.296	17
Area	2	4Rb	10	-0.369	0.133	72
		4Rc	11	-0.337	0.154	67
		4Rd	12	-1.041	0.212	39
Year	3	78	13	0.034	0.279	25
		79	14	-0.086	0.265	33
		80	15	-0.043	0.261	22
		81	16	-0.238	0.264	29
		82	17	-0.615	0.267	24
		83	18	-0.667	0.272	23
		84	19	-0.308	0.272	26
		85	20	0.068	0.358	20
		86	21	0.145	0.313	25
		87	22	0.476	0.311	20

Table 9. Predicted mean catch rate and effort estimates for (A) spring and (B) fall spawning herring in NAFO division 4R from 1977 to 1987.

A) Predicted Spring Spawner Catch Rates:

Standards used. Variable codes: 5 414

Year	Catch		Catch rate		
	Weight	Prop.	Mean	S.E.	Effort
1977	1717	0.230	0.863	0.204	1990
1978	3402	0.505	1.295	0.219	2627
1979	5772	0.653	0.892	0.133	6468
1980	5933	0.636	0.956	0.149	6208
1981	3534	0.758	0.534	0.085	6613
1982	3575	0.733	0.511	0.082	6999
1983	2710	0.601	0.470	0.077	5761
1984	2217	0.800	0.481	0.076	4608
1985	682	0.552	0.443	0.106	1540
1986	1368	0.478	0.867	0.182	1577
1987	1671	0.326	1.185	0.251	1410

Average C.V. for the Mean: .183

B) Predicted Fall Spawner Catch Rates:

Standards used. Variable codes: 8 411

Year	Catch		Catch rate		
	Weight	Prop.	Mean	S.E.	Effort
1977	1589	0.390	0.582	0.142	2729
1978	2609	0.427	0.609	0.118	4282
1979	2629	0.583	0.543	0.091	4843
1980	3578	0.861	0.568	0.089	6297
1981	1971	0.846	0.467	0.077	4223
1982	1693	0.858	0.320	0.056	5295
1983	1238	0.823	0.303	0.054	4082
1984	1242	0.670	0.434	0.079	2862
1985	523	0.441	0.614	0.179	851
1986	779	0.448	0.674	0.161	1155
1987	1172	0.410	0.940	0.217	1246

Average C.V. for the Mean: .202

Table 10. Proportion (%) of spring and fall spawning herring in the purse seine catch by month and fishing area, NAFO division 4R from 1973 to 1987.

	FISHING AREA																		
	4Rd		4Rc								4Rb						4Ra		
SPRING	APR	MAY	JAN	APR	MAY	JUN	JUL	SEPT	OCT	DEC	JAN	APR	AUG	OCT	NOV	DEC	OCT	NOV	DEC
1973	51.3			36.7	64.7						91.3			91.0	90.8				76.7
1974	68.3	39.1														92.6			
1975	98.0	84.7																	87.7
1976	90.4	97.8			52.3												47.3	89.3	
1977	95.4	99.0			32.4													85.8	84.4
1978	82.4			81.9											93.3			91.6	86.7
1979	86.2			43.2	26.0					73.4					88.2				
1980	95.2			98.0										87.3	63.5	55.7			
1981	96.4	92.0		97.3										78.8	77.7				
1982				99.8	98.0			65.0							79.8	68.9		74.7	62.7
1983				61.0	54.5				73.8										
1984			76.4	43.9								40.9		76.9	64.5	60.5		62.0	
1985		92.0			66.0	49.7			82.6				23.8	71.0	70.0	67.7			
1986	77.0	100.0			93.6		78.0							77.3	74.8	71.0			
1987		97.0		100.0	93.0	100.0		65.3	84.7				0	74.5	76.9	72.1		28.0	
FALL																			
1973	48.7			63.3	35.3						8.7			9.0	9.2				23.3
1974	31.7	60.9														7.4			
1975	2.0	15.3																	12.3
1976	9.6	2.2			47.7												52.7	10.7	
1977	4.6	1.0			67.6													14.2	15.6
1978	17.6			18.1											6.7			8.4	13.3
1979	13.8			56.8	74.0					26.6					11.7				
1980	4.8			2.0										12.7	36.5	44.3			
1981	3.6	8.0		2.7										21.2	22.3				
1982				0.2	2.0			35.0							20.2	31.1		25.3	37.3
1983				39.0	45.5				26.2										
1984			23.6	56.1								59.1		23.1	35.5	39.5		38.0	
1985		8.0			34.0	50.3			17.4				76.2	29.0	30.0	32.3			
1986	23.0	0			6.4		22.0							22.7	25.2	29.0			
1987		3.0		0	7.0	0		34.7	15.3				100.0	25.5	23.1	27.9		72.0	

Table 11. Annual weight at age (weighted by landings) for (A) spring and (B) fall spawning herring in NAFO division from 1973 to 1987.

A) ANNUAL SPRING SPAWNER WEIGHT AT AGE (g)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	101	129	77	69	64	103	115	117	85	95	142	134	109	142	165
3	158	172	156	122	156	184	121	201	196	216	190	206	168	171	235
4	224	223	197	193	208	228	234	247	262	263	263	239	247	230	250
5	222	236	242	241	247	275	268	298	327	290	305	297	283	268	289
6	268	262	243	252	278	305	319	321	344	357	337	348	329	315	349
7	303	300	279	269	262	313	343	354	385	386	385	379	373	338	370
8	322	324	301	299	290	318	357	380	415	395	424	406	404	413	390
9	333	351	335	315	313	340	366	398	430	423	434	431	434	415	428
10	350	335	350	334	332	362	373	389	429	434	492	437	425	449	422
11+	367	384	382	382	353	393	409	430	472	454	475	485	477	459	515

B) ANNUAL FALL SPAWNER WEIGHT AT AGE (g)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	131	131	131	131	131	131	131	122	131	166	105	131	50	105	105
3	105	171	120	107	250	161	218	222	204	150	205	164	155	157	187
4	156	218	188	155	229	238	216	242	280	252	218	209	202	214	235
5	231	259	266	282	250	282	281	360	328	306	268	249	258	240	272
6	274	265	297	271	255	316	308	341	358	328	309	293	292	280	319
7	297	284	352	287	301	345	355	404	406	449	338	343	326	317	334
8	329	307	323	277	321	367	381	419	436	441	374	359	347	340	363
9	334	355	370	308	308	366	405	461	485	444	430	429	374	356	364
10	346	378	391	426	330	390	408	468	498	485	462	450	444	363	390
11+	382	422	465	454	421	471	458	534	515	507	503	494	432	465	513

Table 12. Annual gillnet weight at age (weighted by landings) for (A) spring and (B) fall spawning herring in NAFO division 4R from 1973 to 1987.

A) ANNUAL SPRING SPAWNER GILLNET WEIGHT AT AGE (g)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	89	105	77	67	64	84	101	94	85	85	84	101	71	71	71
3	228	200	156	218	225	272	121	215	189	227	209	208	163	224	146
4	233	223	253	223	264	257	228	227	259	264	250	245	235	230	245
5	241	244	239	240	259	283	269	293	316	279	286	296	262	277	261
6	284	263	242	256	282	316	324	311	332	316	316	346	306	298	298
7	316	312	288	281	283	324	334	345	367	381	365	379	352	319	327
8	345	319	354	300	300	318	339	366	398	386	409	334	350	369	350
9	341	343	375	297	320	342	364	389	412	386	383	441	400	391	361
10	353	332	470	325	351	360	366	381	415	427	530	427	405	404	334
11+	371	375	401	366	384	384	402	416	456	457	455	474	445	439	451

B) ANNUAL FALL SPAWNER GILLNET WEIGHT AT AGE (g)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	105	105	105	105	105	105	105	122	131	131	105	131	131	105	105
3	171	171	120	131	150	161	218	222	204	147	242	164	149	157	157
4	231	241	222	155	249	238	241	275	281	279	259	273	272	313	267
5	252	277	280	299	276	292	301	370	337	318	297	287	296	261	287
6	302	273	312	281	297	343	334	342	371	352	326	341	305	298	330
7	338	296	384	300	332	370	381	410	409	504	393	356	338	337	349
8	379	299	341	298	363	393	404	417	446	452	407	400	353	387	372
9	372	373	394	316	341	387	441	469	526	486	449	440	350	388	372
10	412	388	417	426	373	422	437	469	504	507	474	438	422	336	411
11+	442	458	491	486	446	524	497	546	531	546	517	496	479	484	486

Table 13. Gillnet selectivity at age, derived from gillnet partiel F matices normalized to the mean of the three highest F's, for (A) spring and (B) fall spawning herring in NAFO division 4R from 1973 to 1987.

A) SPRING SPAWNER GILLNET SELECTIVITY AT AGE

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.001	.000	.000	.000	.000
3	.002	.030	.000	.046	.005	.003	.000	.038	.031	.028	.013	.001	.000	.001	.000
4	.008	.000	1.000	.000	.013	.078	.026	.045	.545	.104	.177	.032	.019	.038	.119
5	.061	.014	.050	.000	.117	.138	.512	.064	.054	1.000	.416	.225	.169	.079	.474
6	.089	.191	.235	.038	.500	.203	.569	1.000	.097	.148	.992	.349	.378	.416	.725
7	.272	.165	.547	.330	.336	.308	.745	.258	1.000	.305	.093	1.000	.637	.688	.779
8	.491	.319	.757	.621	.570	.950	1.000	.751	.110	1.000	.023	.168	1.000	.783	1.000
9	.933	.341	.315	.565	.602	.486	1.000	.587	.307	.446	1.000	.478	.709	1.000	.614
10	.278	.460	.740	1.000	1.000	.854	.848	1.000	.604	.667	.694	.745	.868	.761	1.000
11+	1.000	1.000	.973	1.000	1.000	1.000	.884	.724	.399	.796	.877	.927	.869	.691	.914

B) FALL SPAWNER GILLNET SELECTIVITY AT AGE

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000	.000
3	.000	.000	.000	.000	.007	.000	.000	.000	.000	.000	.003	.000	.000	.000	.000
4	.027	.254	.011	.000	.031	.019	.026	.035	.141	.097	.037	.016	.003	.002	.058
5	.227	.669	.280	.029	.075	.207	.340	.193	.288	.295	.185	.128	.044	.067	.250
6	1.000	.263	1.000	.349	.246	.426	.613	.233	.117	.336	.538	.219	.316	.144	.532
7	1.000	1.000	.142	.592	.984	1.000	.319	.863	.700	.557	.472	.693	.431	.356	.826
8	.742	.611	.550	.986	.769	1.000	1.000	.214	1.000	.870	.858	.514	.833	.374	.971
9	.893	1.000	1.000	.920	1.000	.496	1.000	1.000	.152	1.000	1.000	1.000	.903	.670	1.000
10	.477	.517	.616	1.000	.879	.652	.699	.931	.766	1.000	.841	1.000	.322	.920	1.000
11+	.833	.975	.530	.730	.731	.909	.498	.916	.946	.912	.537	.858	1.000	1.000	.825

Table 14. Average gillnet fishable biomass for (A) spring and (B) fall spawning herring in NAFO division 4R from 1973 to 1987.

A) SPRING SPAWNER AVERAGE FISHABLE BIOMASS (t)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	0	0	0	0	0	0	0	2	0	0	32	1	0	0	0
3	17	60	0	172	128	16	0	114	74	511	1103	20	6	16	0
4	346	0	2014	0	46	1699	102	83	1467	274	2818	2533	267	1810	1330
5	5501	560	344	0	453	417	9132	263	110	1846	877	3269	11464	1056	19735
6	693	14281	7351	228	690	763	1545	13561	358	241	1108	627	4321	23938	7877
7	4056	1047	35499	9744	1789	374	2222	572	9004	1011	133	747	859	5944	34287
8	2930	3689	4394	32937	14228	4475	925	1745	219	5080	53	166	391	796	6301
9	3034	1379	3440	2205	25421	10655	3572	423	541	659	2281	800	637	237	421
10	1901	913	3148	7583	3516	28711	13893	2277	329	859	926	913	923	499	126
11+	8100	9821	9613	9630	13521	11721	30108	26760	11302	14722	9910	6982	4707	3157	3450
2+	26579	31751	65804	62500	59792	58830	61499	45800	23403	25202	19241	16057	23574	37453	73525

B) FALL SPAWNER AVERAGE FISHABLE BIOMASS (t)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	13	0	0	0	0	20	54	0	0	0	0
4	101	1092	24	0	170	26	17	64	736	941	2951	313	52	34	587
5	618	2266	1117	74	148	1057	475	146	518	1380	1482	9200	750	922	3124
6	3073	574	2925	1075	481	822	2726	283	70	493	1953	1571	9362	1959	7188
7	1591	1898	343	1252	2758	1797	516	3032	774	343	554	2003	2375	18678	10126
8	3469	499	895	1456	1476	2410	1202	275	2547	772	308	423	1769	1824	43544
9	3887	3024	783	1090	1284	769	1601	606	187	1813	578	259	480	1145	3580
10	10664	1345	1633	642	938	777	848	691	284	861	955	305	53	353	1352
11+	42101	53414	25728	29438	21256	23599	9370	13486	9915	7070	3087	3570	2370	1909	1597
2+	65504	64112	33447	35027	28523	31256	16755	18584	15031	13693	11922	17643	27210	26823	71098

Table 15. Cohort analysis calibration results (correlation coefficients, sums of squares of the standardized residuals of the last three years, and the residual of the last year) from the linear regression of gillnet fishable biomass (spring and fall spawners), estimated at various F values, and standardized gillnet catch rates.

SPRING SPAWNERS				
F	0.085	0.10	0.115	0.125
r	.89	.90	.89	.88
S.S. LAST 3 ST. RES.	.0986	.0634	.0638	.0760
RES. OF LAST POINT	.2128	.1119	.0279	-.0209
FALL SPAWNERS				
F	0.03	0.04	0.05	0.085
r	.87	.89	.90	.85
S.S. LAST 3 ST. RES.	.1177	.1179	.1298	.1838
RES. OF LAST POINT	.2881	.2530	.2151	.1125

Table 16. Second quarter population biomass for spring spawning herring in NAFO division 4R from 1973 to 1987.

SPRING SPAWNER SECOND QUARTER POPULATION BIOMASS (t)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	1488	4065	1713	9237	1742	1305	2088	1939	8818	48799	13373	44704	8127	7303	8483
3	7210	1811	4002	2223	17070	4091	1255	2959	2599	18300	79922	15854	45804	10391	9819
4	45841	8244	1654	3898	2967	20294	4263	2088	2974	2765	17720	81498	15519	50503	11953
5	87669	39282	7302	1569	3891	3088	19051	4391	2237	2168	2440	15469	77061	13579	48622
6	7718	78331	33071	6209	1434	3830	2875	15722	4044	1958	1349	1938	12987	64452	13463
7	15162	6414	66143	29624	5204	1244	3325	2427	10809	3597	1590	887	1510	9760	52739
8	5993	12401	5192	55804	25529	5075	1086	2666	2185	6073	2447	1272	491	1212	7449
9	3484	4368	10247	4364	43659	23180	4097	804	1974	1752	3044	1771	1033	278	857
10	7193	2121	3337	8279	3550	36329	18193	2637	618	1438	1371	1383	1185	777	170
11+	8986	10771	9930	10822	13373	13088	37811	42018	31699	20372	13230	8585	6160	5078	4569
2+	190743	167807	142592	132027	118419	111522	94043	77650	67956	107221	136486	173360	169878	163333	158124
3+	189255	163742	140879	122790	116677	110218	91955	75712	59139	58422	123113	128656	161751	156029	149640
4+	182046	161932	136877	120567	99607	106127	90700	72753	56540	40122	43191	112802	115947	145638	139822
5+	136205	153688	135223	116669	96640	85833	86438	70665	53565	37357	25471	31304	100428	95135	127869

Table 17. Fishing mortalities, estimated from cohort analysis, for spring spawning herring in NAFO division 4R from 1973 to 1987.

SPRING SPAWNER FISHING MORTALITY

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	.140	.005	.003	.004	.000	.000	.010	.019	.000	.001	.000	.001	.005	.007	.009
3	.010	.026	.042	.040	.005	.002	.003	.063	.034	.030	.007	.006	.018	.041	.008
4	.005	.004	.054	.045	.041	.024	.012	.013	.218	.072	.057	.024	.013	.068	.063
5	.077	.002	.003	.033	.028	.020	.174	.026	.020	.423	.161	.080	.087	.072	.100
6	.098	.034	.008	.015	.064	.058	.075	.354	.032	.084	.337	.119	.113	.160	.100
7	.070	.016	.038	.027	.019	.066	.124	.065	.403	.279	.078	.455	.123	.212	.100
8	.202	.024	.020	.092	.054	.154	.210	.225	.038	.586	.139	.073	.399	.182	.100
9	.303	.068	.012	.059	.128	.135	.302	.138	.126	.197	.595	.189	.119	.304	.100
10	.279	.085	.027	.142	.181	.173	.173	.249	.230	.356	.355	.287	.154	.171	.100
11+	.279	.085	.027	.142	.181	.173	.173	.249	.230	.356	.355	.287	.154	.171	.100
5+	.103	.027	.025	.074	.103	.147	.174	.250	.227	.369	.316	.146	.095	.151	.100

Table 18. Population numbers, estimated from cohort analysis, for spring spawning herring in NAFO division 4R from 1973 to 1987.

SPRING SPAWNER POPULATION NUMBERS ('000)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	15560	33098	23388	140790	28618	13304	19135	17356	109056	539370	99001	350887	78473	54049	54047
3	47935	11081	26971	19097	114831	23421	10893	15515	13939	89251	441061	81025	287103	63920	43959
4	214754	38852	8836	21181	15019	93533	19134	8895	11930	11035	70925	358427	65946	230910	50209
5	414938	174864	31692	6854	16576	11807	74780	15472	7187	7855	8408	54845	286422	53280	176600
6	30316	314503	142831	25857	5430	13201	9479	51427	12346	5768	4212	5861	41457	214919	40592
7	52690	22495	248947	115978	20853	4171	10194	7203	29553	9788	4341	2462	4260	30329	149919
8	19551	40224	18129	196192	92419	16758	3197	7374	5528	16168	6065	3289	1279	3085	20089
9	10995	13082	32162	14556	146542	71720	11765	2122	4821	4356	7367	4321	2504	703	2105
10	21625	6652	10011	26029	11231	105538	51293	7124	1514	3482	2929	3326	2929	1819	425
11+	25720	29520	27294	29786	39797	35010	97207	102739	70564	47154	29274	18627	13583	11636	9328
2+	854083	684369	570261	596318	491318	388463	307076	235227	266438	734226	673584	883070	783955	664650	547273
3+	838523	651271	546873	455528	462700	375159	287941	217871	157382	194856	574582	532183	705482	610601	493226
4+	790589	640191	519903	436432	347869	351737	277048	202356	143444	105605	133521	451158	418379	546680	449267
5+	575835	601339	511067	415251	332849	258205	257915	193461	131514	94570	62596	92730	352433	315771	399057

Table 19. Mid-year population biomass for fall spawning herring in NAFO division 4R from 1973 to 1987.

FALL SPAWNER MID-YEAR POPULATION BIOMASS (t)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	2011	1752	4246	1143	521	1324	3698	6373	60635	17573	10361	10726	2837	3547	3548
3	2472	2142	1313	2838	1785	524	1802	5122	8732	56913	17766	13176	10380	7269	5171
4	2535	3894	1934	1385	4973	1392	574	1634	5244	8797	67439	14825	13317	11675	8836
5	2510	3194	3810	2360	1776	4965	1338	748	1780	4569	7286	62630	14812	12667	11846
6	2892	2118	2860	2984	1689	1803	4295	1235	585	1392	3530	6191	58681	12721	13099
7	1449	1848	2215	2046	2613	1757	1543	3729	1145	567	1032	2842	5325	49554	11810
8	4160	844	1563	1399	1731	2385	1243	1314	2677	911	344	750	2096	4303	43993
9	4024	2907	753	1177	1195	1494	1596	743	1145	1783	594	267	571	1581	3530
10	19032	2549	2525	659	966	1126	1194	803	383	878	1152	337	173	420	1301
11+	44963	50995	46414	38249	27944	24153	17982	15588	10765	7579	5740	4263	2158	1864	2056
2+	86049	72245	67634	54241	45192	40923	35265	37289	93091	100962	115244	116006	110350	105600	105191
3+	84037	70492	63388	53098	44671	39599	31567	30917	32456	83389	104884	105280	107513	102053	101643
4+	81566	68350	62075	50260	42887	39075	29765	25795	23724	26476	87117	92104	97133	94784	96472
5+	79030	64456	60141	48874	37913	37683	29192	24161	18480	17679	19678	77279	83816	83109	87636
6+	76520	61262	56330	46514	36137	32718	27854	23413	16700	13109	12392	14649	69004	70443	75790

Table 20. Fishing mortalities, estimated from cohort analysis, for fall spawning herring in NAFO division 4R from 1973 to 1987.

FALL SPAWNER FISHING MORTALITY

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.001	.000
3	.079	.002	.002	.002	.000	.003	.001	.008	.001	.001	.001	.001	.004	.009	.006
4	.076	.022	.004	.031	.008	.005	.045	.020	.028	.054	.008	.009	.021	.027	.013
5	.108	.044	.062	.035	.019	.031	.075	.042	.046	.066	.051	.025	.034	.052	.032
6	.286	.041	.101	.039	.063	.071	.214	.050	.057	.128	.122	.056	.049	.052	.050
7	.375	.096	.017	.082	.087	.246	.127	.207	.111	.118	.181	.116	.057	.055	.050
8	.233	.099	.033	.066	.078	.301	.502	.083	.224	.201	.190	.111	.109	.065	.050
9	.382	.038	.075	.068	.093	.132	.632	.541	.067	.277	.413	.268	.078	.090	.050
10	.162	.047	.034	.059	.105	.125	.173	.197	.175	.191	.283	.438	.098	.058	.050
11+	.162	.047	.034	.059	.105	.125	.173	.197	.175	.191	.283	.438	.098	.058	.050
6+	.190	.050	.039	.059	.098	.145	.221	.192	.166	.191	.216	.160	.053	.056	.050

Table 21. Population numbers, estimated from cohort analysis, for fall spawning herring in NAFO division 4R from 1973 to 1987.

FALL SPAWNER POPULATION NUMBERS ('000)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
2	16955	14773	35794	9636	4391	11158	31173	57730	511148	116994	108735	90420	62578	37336	37340
3	26113	13882	12095	29305	7889	3595	9135	25522	47252	418493	95696	89011	74030	51221	30537
4	17925	19752	11348	9885	23949	6456	2934	7473	20732	38657	342120	78274	72827	60398	41550
5	12028	13608	15816	9255	7848	19455	5262	2298	5995	16499	29999	277996	63480	58413	48155
6	11670	8839	10661	12166	7315	6304	15435	3996	1803	4687	12644	23335	221941	50248	45408
7	5396	7178	6943	7892	9579	5623	4806	10205	3112	1395	3376	9167	18067	172952	39066
8	13964	3036	5342	5588	5954	7191	3601	3464	6790	2282	1015	2307	6684	13976	133982
9	13333	9052	2252	4231	4281	4508	4359	1784	2610	4442	1527	687	1689	4909	10724
10	60870	7451	7133	1711	3236	3195	3236	1897	850	1999	2757	827	430	1279	3672
11+	130007	133507	110331	93139	73423	56699	43437	32276	23094	16533	12600	9539	5524	4435	4426
2+	308260	231078	217714	182809	147865	124185	123379	146645	623388	621981	610470	581564	527250	455167	394859
3+	291305	216304	181920	173173	143474	113027	92206	88915	112239	504987	501735	491144	464672	417831	357520
4+	265193	202423	169825	143868	135584	109432	83070	63393	64988	86494	406039	402132	390643	366610	326983
5+	247267	182671	158477	133982	111635	102976	80136	55920	44256	47837	63919	323858	317816	306212	285433
6+	235240	169063	142662	124728	103787	83520	74874	53622	38260	31338	33920	45862	254336	247799	237277

Table 22. Population and catch estimates for spring spawning herring in NAFO division 4R from 1987 to 1989 assuming a fully recruited fishing mortality rate of 0.3 in 1988 and 1989.

	POPULATION NUMBERS ('000)				FISHING MORTALITY				SECOND QUARTER POPULATION BIOMASS (t)		
	1987	1988	1989		1987	1988	1989		1987	1988	1989
2	54047	54047	54047	2	.009	.011	.011	2	8483	8483	8483
3	43959	43840	43785	3	.008	.108	.108	3	9819	9792	9780
4	50209	35693	32208	4	.063	.189	.189	4	11953	8497	7667
5	176600	38598	24191	5	.100	.300	.300	5	48622	10627	6660
6	40592	130829	23411	6	.100	.300	.300	6	13463	43391	7765
7	149919	30071	79352	7	.100	.300	.300	7	52739	10578	27914
8	20089	111063	18239	8	.100	.300	.300	8	7449	41183	6763
9	2105	14882	67363	9	.100	.300	.300	9	857	6057	27417
10	425	1560	9027	10	.100	.300	.300	10	170	626	3622
11+	9328	315	946	11+	.100	.300	.300	11+	4569	154	463
12+		6910	191	12+		.300	.300	12+		3385	93
13+			4191	13+			.300	13+			2053
2+	547273	467807	356949	2+	.080	.240	.223	2+	158124	142774	108681
3+	493226	413760	302902					3+	149640	134291	100198
4+	449267	369920	259117					4+	139822	124499	90418
5+	399057	334227	226910					5+	127869	116001	82751

	CATCH NUMBERS ('000)				CATCH BIOMASS (t)		
	1987	1988	1989		1987	1988	1989
2	455	516	516	2	75	85	85
3	329	4087	4082	3	77	960	958
4	2781	5589	5043	4	696	1399	1262
5	15257	9112	5711	5	4416	2637	1653
6	3507	30886	5527	6	1223	10769	1927
7	12952	7099	18733	7	4790	2625	6928
8	1736	26220	4306	8	677	10221	1679
9	182	3513	15903	9	78	1503	6805
10	37	368	2131	10	15	155	899
11+	806	74	223	11+	415	38	115
12+		1631	45	12+		840	23
13+			989	13+			509
2+	38041	89096	63209	2+	12462	31233	22843
3+	37587	88580	62694	3+	12387	31148	22758
4+	37258	84494	58612	4+	12310	30189	21800
5+	34476	78905	53569	5+	11613	28790	20538

Table 23. Population and catch estimates for fall spawning herring in NAFO division 4R from 1987 to 1989 assuming a fully recruited fishing mortality rate of 0.3 in 1988 and 1989.

	POPULATION NUMBERS ('000)				FISHING MORTALITY				MID-YEAR POPULATION BIOMASS (t)		
	1987	1988	1989		1987	1988	1989		1987	1988	1989
2	37340	37340	37340	2	.000	.004	.004	2	3548	3548	3548
3	30537	30570	30440	3	.006	.064	.064	3	5171	5177	5155
4	41550	24860	23466	4	.013	.078	.078	4	8836	5287	4990
5	48155	33579	18826	5	.031	.189	.189	5	11846	8260	4631
6	45408	38204	22758	6	.050	.300	.300	6	13099	11021	6565
7	39066	35364	23172	7	.050	.300	.300	7	11810	10691	7005
8	133982	30424	21449	8	.050	.300	.300	8	43993	9990	7043
9	10724	104345	18453	9	.050	.300	.300	9	3530	34346	6074
10	3672	8352	63289	10	.050	.300	.300	10	1301	2959	22421
11+	4426	2860	5066	11+	.050	.300	.300	11+	2056	1329	2354
12+		3447	1735	12+		.300	.300	12+		1601	806
13+			2091	13+			.300	13+			971
2+	394859	349344	268084	2+	.036	.221	.205	2+	105191	94209	71563
3+	357520	312005	230744					3+	101643	90661	68015
4+	326983	281435	200304					4+	96472	85485	62861
5+	285433	256575	176838					5+	87636	80198	57870
6+	237277	222995	158011					6+	75790	71937	53239

	CATCH NUMBERS ('000)				CATCH BIOMASS (t)		
	1987	1988	1989		1987	1988	1989
2	1	145	145	2	0	15	15
3	156	1732	1724	3	29	324	323
4	487	1693	1598	4	114	398	376
5	1354	5258	2948	5	368	1429	801
6	2009	9019	5373	6	640	2876	1713
7	1728	8349	5470	7	577	2789	1828
8	5927	7183	5064	8	2151	2606	1838
9	474	24634	4356	9	173	8961	1585
10	162	1972	14941	10	64	772	5850
11+	196	675	1196	11+	101	347	614
12+		814	410	12+		418	210
13+			494	13+			253
2+	12495	61472	43718	2+	4217	20936	15405
3+	12494	61327	43574	3+	4217	20921	15390
4+	12338	59596	41849	4+	4188	20596	15068
5+	11851	57903	40251	5+	4074	20199	14692
6+	10497	52645	37304	6+	3706	18769	13891

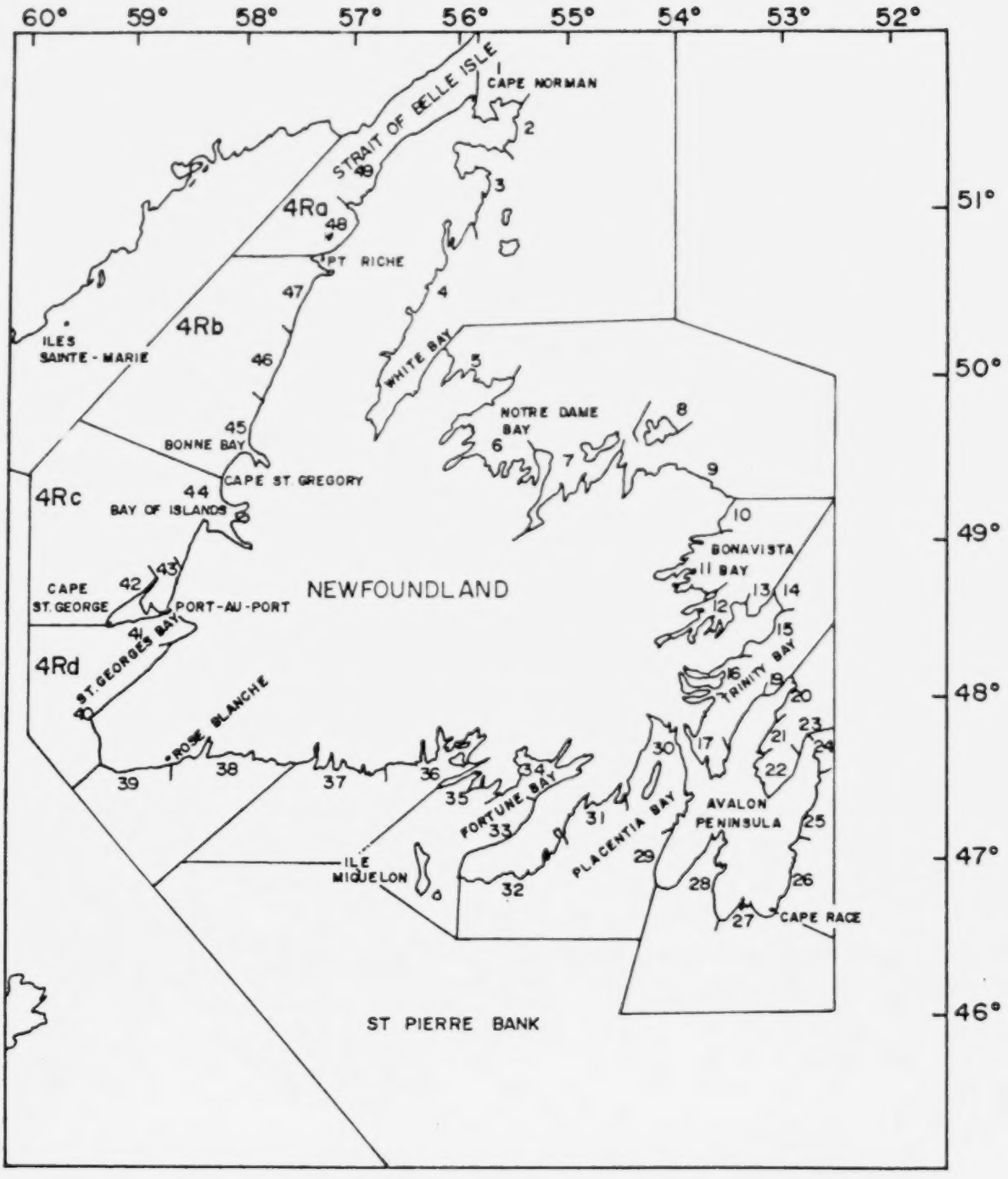


Figure 1. West coast of Newfoundland unit areas and statistical districts.

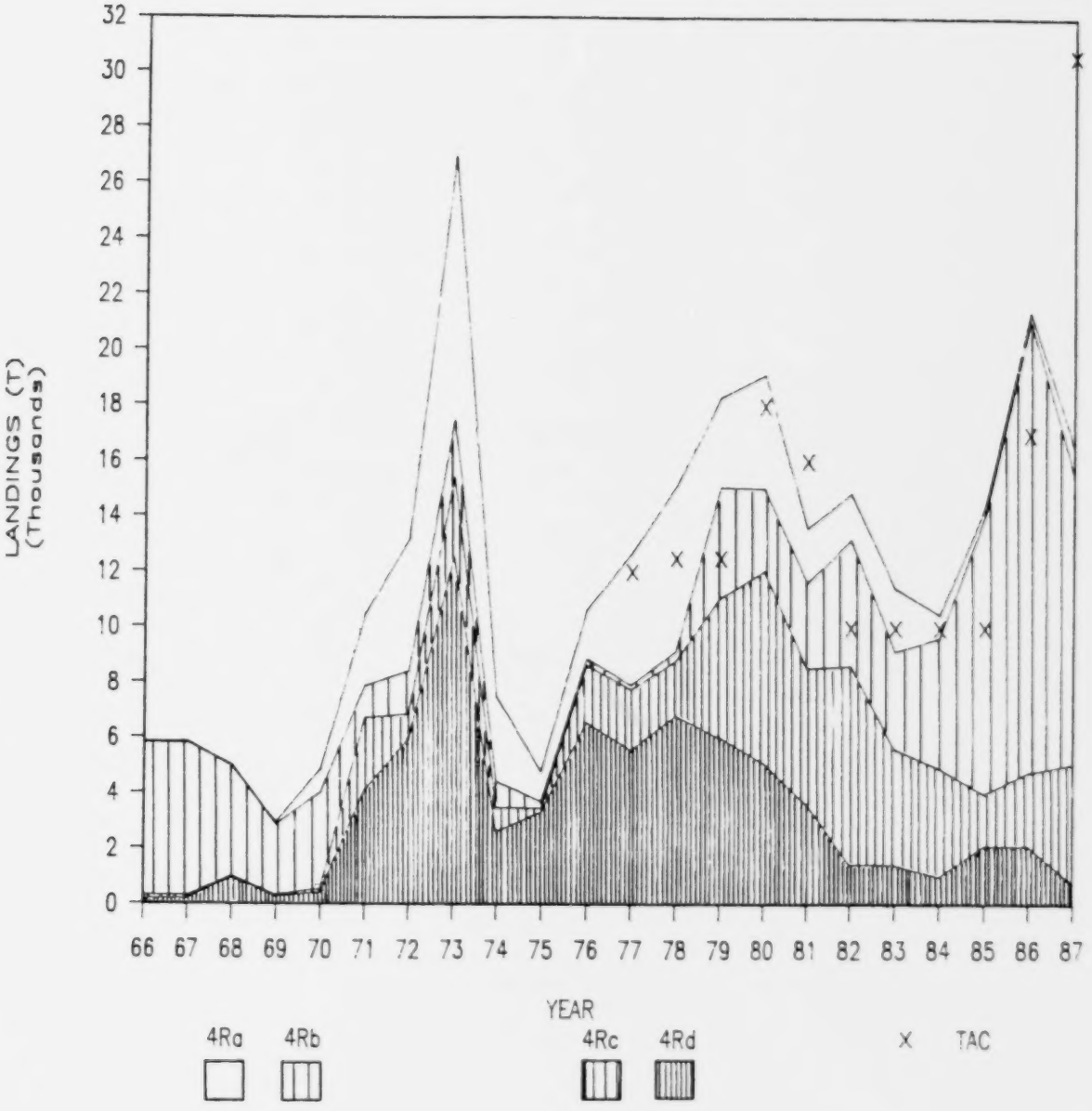


Figure 2. Commercial herring landings (t) by fishing area from NAFO division 4R from 1966 to 1987 ("X" indicate annual TAC's).

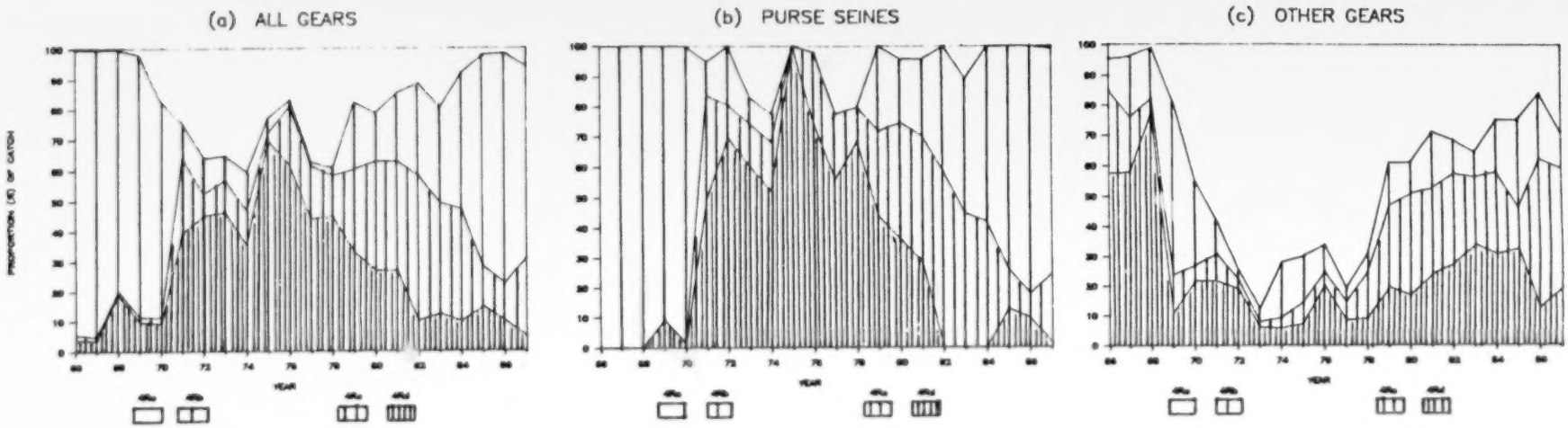


Figure 3. Proportion of herring catches from each fishing area from 1966 to 1987 for (a) all gears combined, (b) purse seines, and (c) all other gears (mainly gillnets).

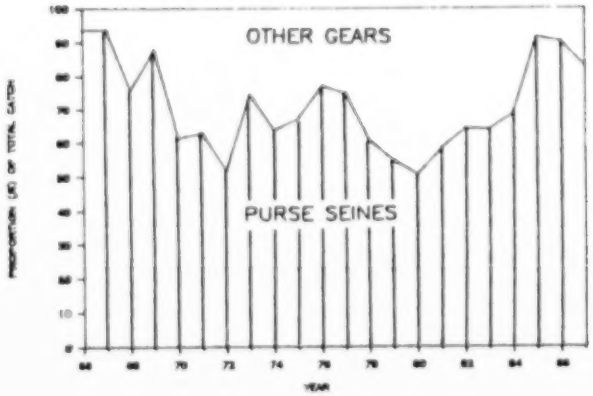


Figure 4. Proportion of total herring catches taken by purse seines and all other gears in NAFO division 4R from 1966 to 1987.

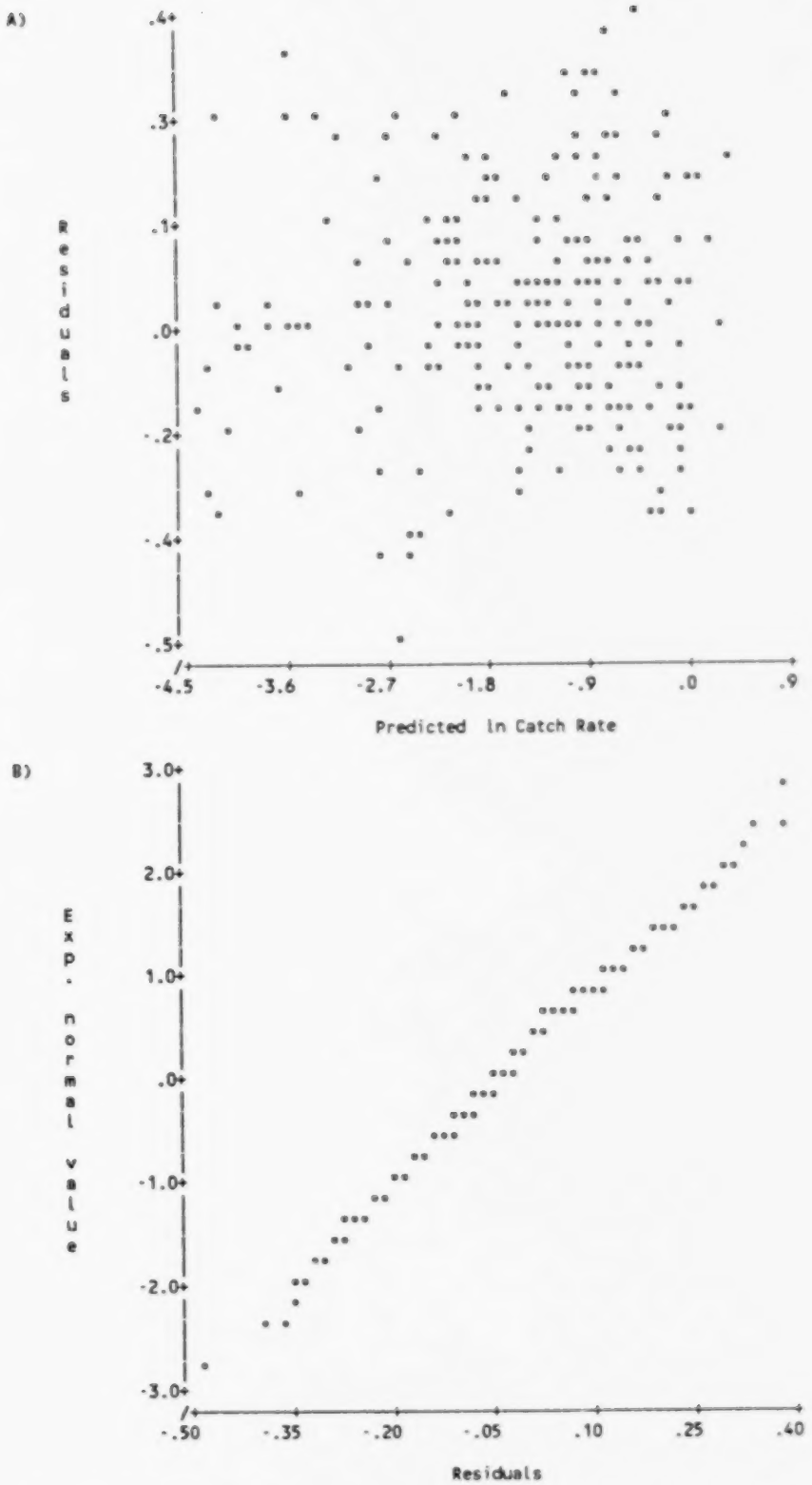
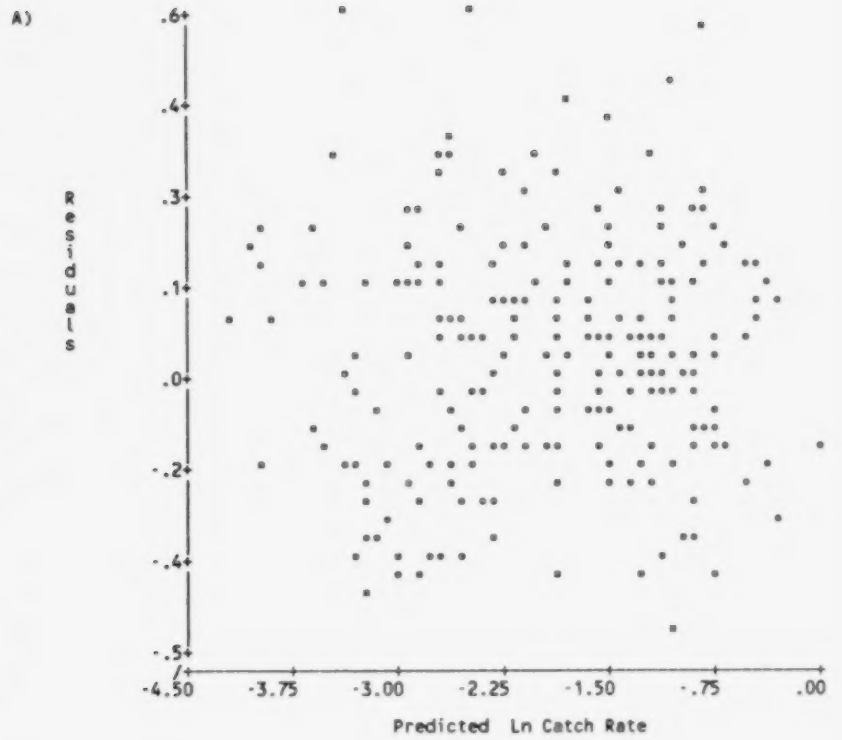


Figure 5. (A) Distribution of residuals over predicted ln catch rate and (B) expected normal value versus residuals from the multiplicative model for spring spawning herring in NAFO division 4R.



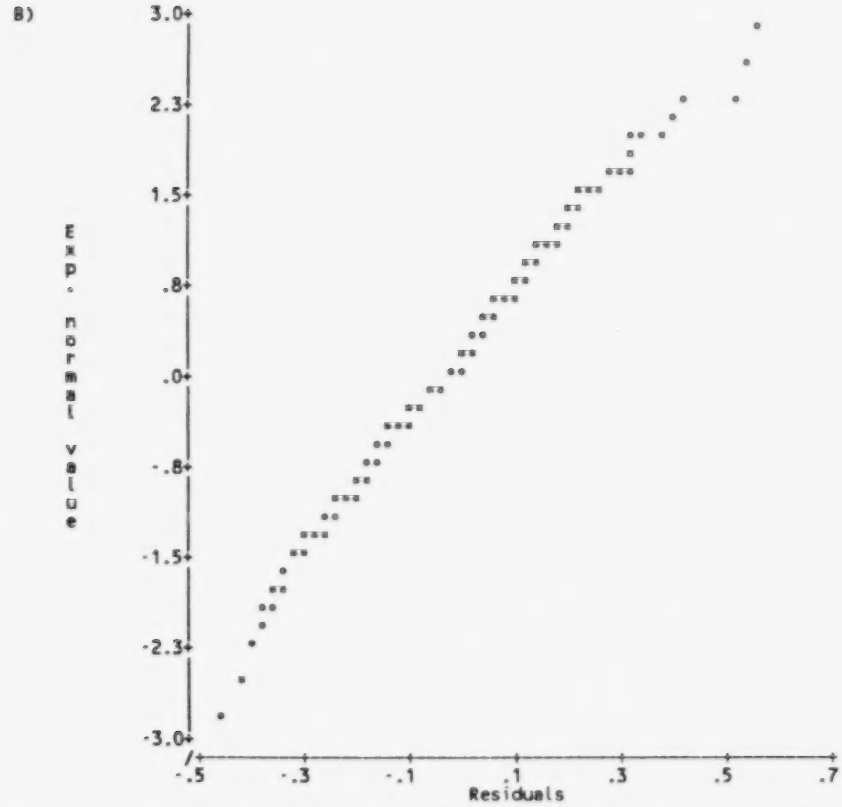


Figure 6. (A) Distribution of residuals over ln catch rate and (B) expected normal value versus residuals from the multiplicative model for fall spawning herring in NAFO division 4R.

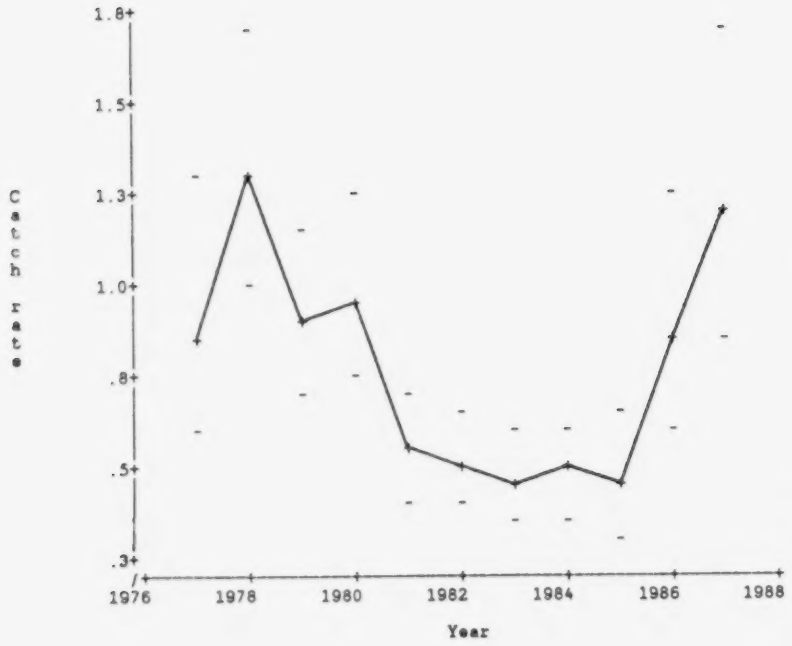


Figure 7. Standardized mean gillnet catch rates (with approximate 90% confidance intervals) for spring spawning herring in NAFO division 4R from 1977 to 1987 fitted from purchase slip data by the multiplicative model.

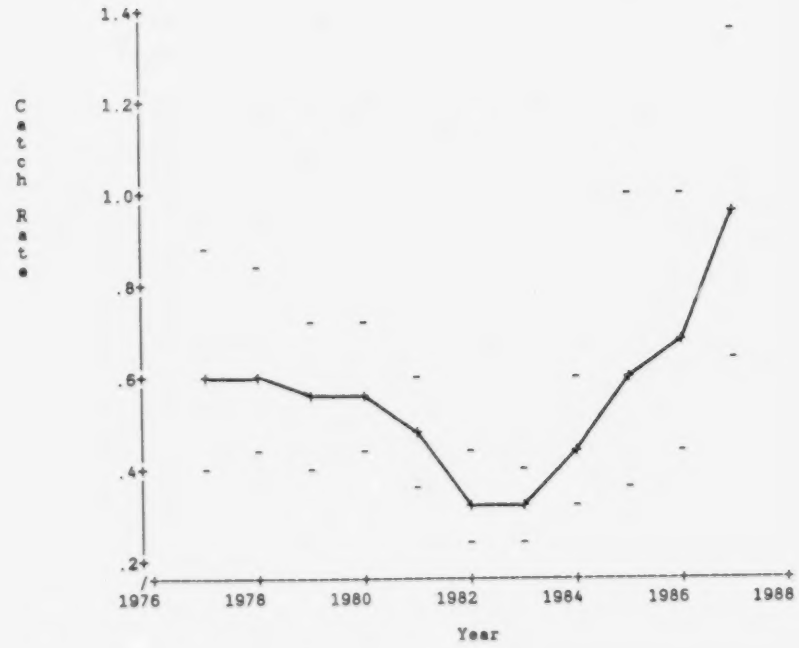


Figure 8. Standardized mean gillnet catch rates (with approximate 90% confidance intervals) for fall spawning herring in NAFO division 4R from 1977 to 1987 fitted from purchase slip data by the multiplicative model.

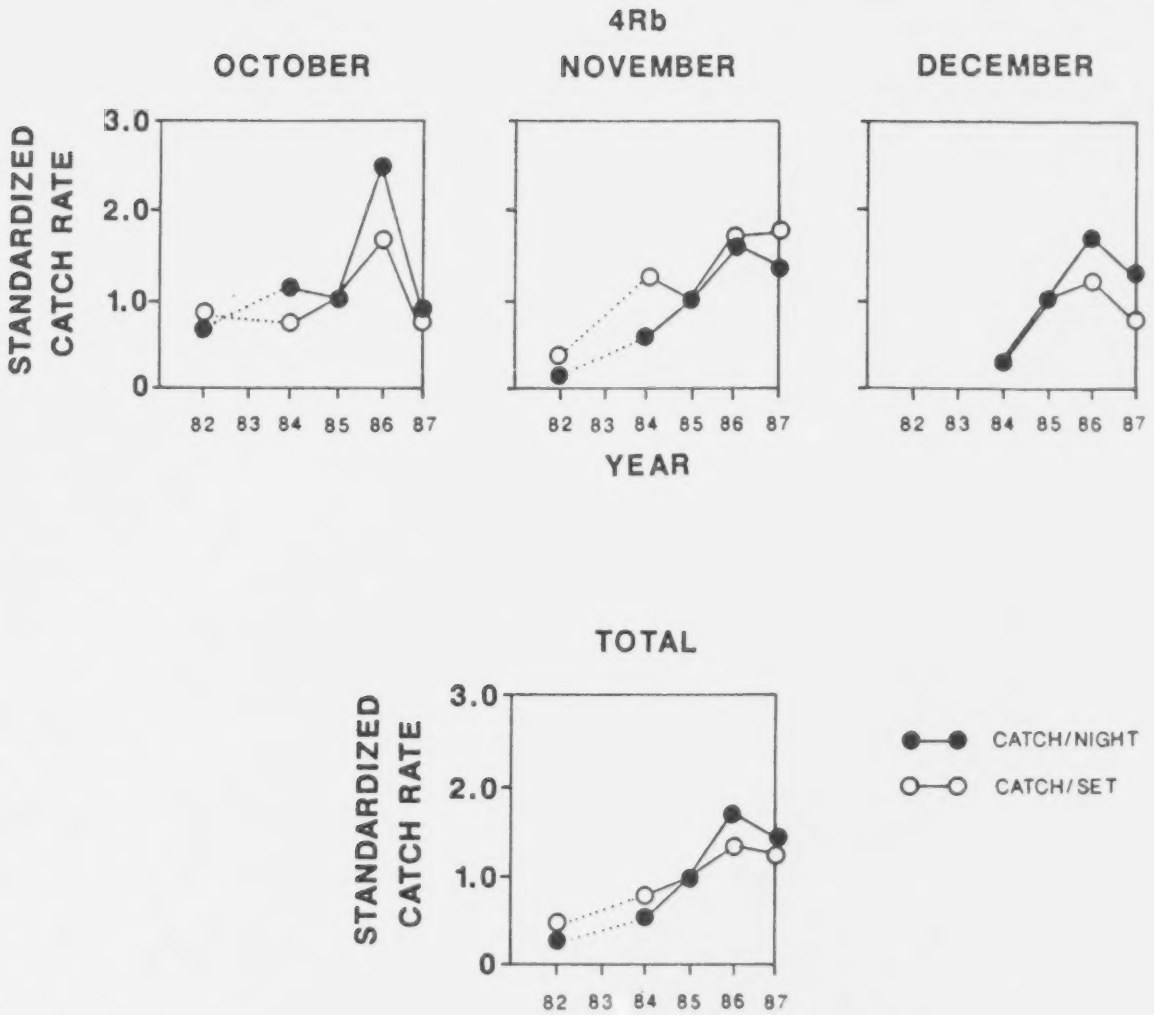
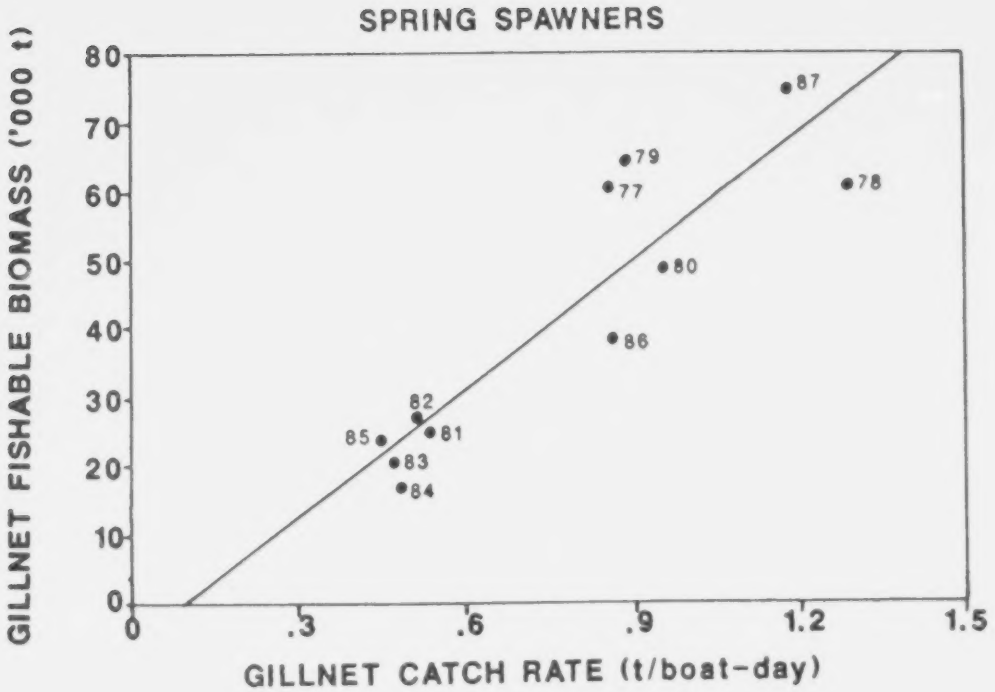


Figure 9. Purse seine catch rates from observer logbooks, standardized to 1985, from the NAFO division 4Rb fall mixed fishery from 1982 to 1987.

A)



B)

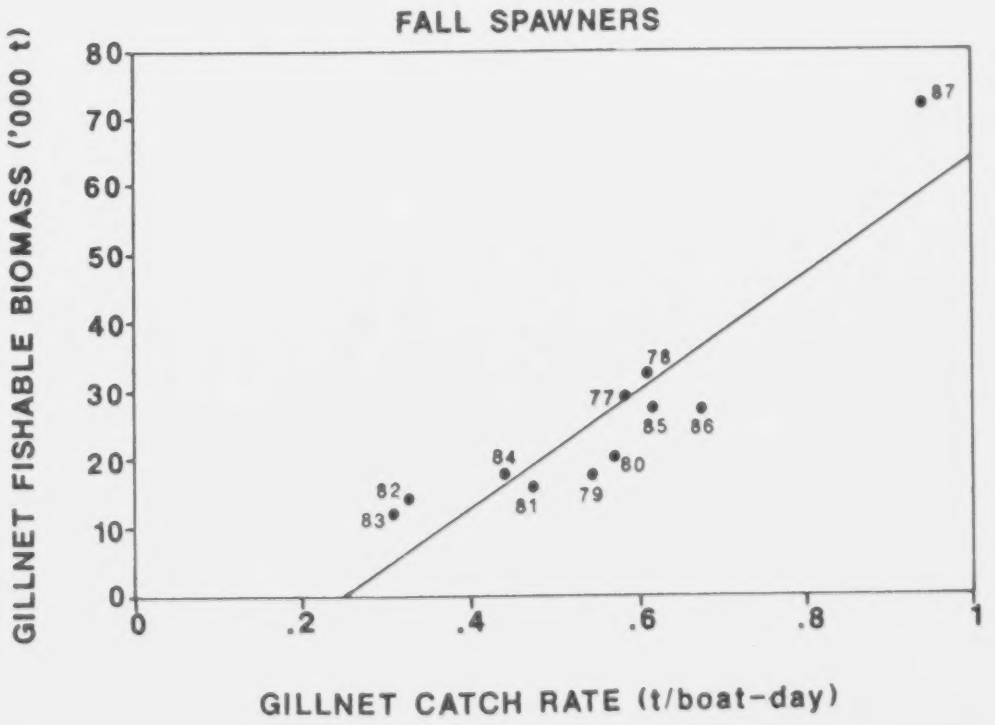


Figure 10. Least squares regression of gillnet fishable biomass and standardized gillnet catch rate from 1977 to 1987 for (a) spring spawners and (b) fall spawners.

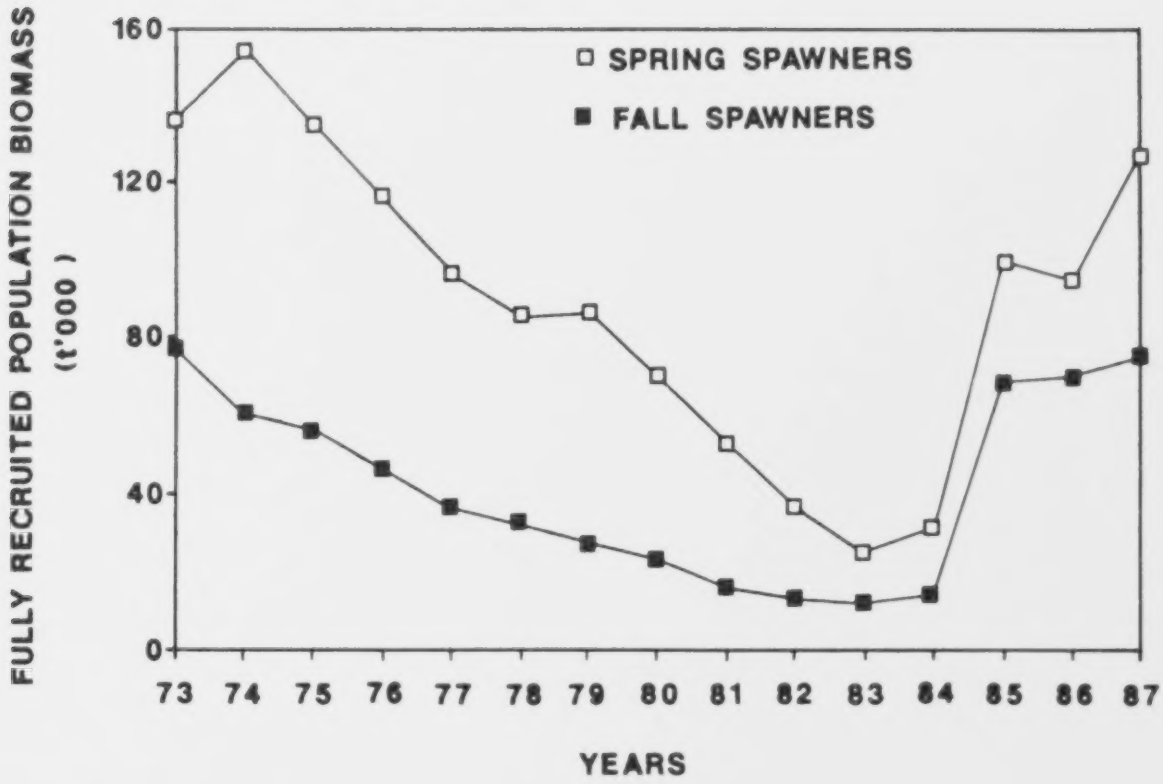


Figure 11. Fully recruited population biomass for spring spawning (5+) and fall spawning (6+) herring in NAFO Division 4R from 1973 to 1987.

Annex 1. Number of herring sampled (bold print) and commercial landings (t) in NAFO division 4R by gear, area and month in 1987.

GEAR	AREA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
GN	4Ra								1	2	3	4	
						19	**21**	**14**	**142**	**65**	**192**	**353**	**23**
											5		
	4Rb										**92**		
		1	*	**1**	**15**	**22**	**23**	**11**	**7**	**5**	**87**	**135**	**20**
					6	7	8						
	4Rc				**100**	**615**	**228**						
					146	**580**	**96**	**78**	**52**	**13**	**55**	**117**	**1**
					9	10							
	4Rd				**299**	**496**							
					146	**319**	**30**	**23**	**8**	**8**	**13**	**4**	**1**
PS	4Ra											1	
												50	
												165	
	4Rb					6			2		3	4	5
						25			**50**		**247**	**347**	**290**
									14		**748**	**4426**	**4952**
	4Rc						7			8	9		
					50	**100**	**50**			**49**	**150**		
						1319	**596**			**153**	**565**	**379**	**171**
	4Rd					10							
						99							
						222							

* : <1t